THE EVALUATION OF SUCCESS IN NAVAL SHIP ACQUISITION

Virgil Frank McCaleb

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NAVAL SHIP ACQUISITION

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ABSTRACT

An overview of post World War II U.S. naval ship acquisition policies and results is presented. The major emphasis in the overview is on several new control systems and policies announced since 1970.

A case for development of a comprehensive, life-cycle ship success evaluation system is based on the current dominant emphasis on short-term goal achievement and the need for a centralized, complete historical record and data bank on ship acquisitions.

Success in naval ship acquisitions is defined as how well actual results match a set of prioritized goals determined from the requirements of the military need. Individual sets of criteria for performance, cost and schedule goals are developed. Two schemes for evaluating overall ship

acquisition success, a "manual" model and a computerized simulation model, are outlined.

The development of a comprehensive life-cycle ship acquisition evaluation system is recommended. Further study and development of certain aspects of the proposed system are required.

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Thesis Advisor: Peter Lorange

Title: Assistant Professor of Management

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INTRODUCTION

The following excerpts are taken from an article in the March 4, 1976, edition of the Boston Globe.

> " a ..... shipbuilder (is) seeking payment of $11,708 ..... owed by the Federal Government for a Navy (ship) ...... the 300 foot (ship) cost the ..... Navy $75,000, plus a $16,000 overrun resulting from requested modifications and delays in subcontract work, ... the unpaid debt was a major reason why (the shipyard) ultimately went bankrupt ....."

Only the magnitude of the figures set this article apart from similar, almost daily expositions. Generally such paltry sums as above are not newsworthy. A $160,000,000 overrun would be more like it. Actually the article refers to a claim filed by descendants of the shipbuilder over a disputed unpaid bill resulting from construction of a Union Navy gunboat during the Civil War. As in todays similar reports, the ultimate "success" of the gunboat - or failure - is left unaddressed.

In the conclusion of an exhaustive study by Dallen, Merkl and Zlatoper of the Army's ill-fated main battle tank (MBT-70) program, it is noted that various players in the

weapons acquisition process view "success" quite differently.[1] The authors observed that the strength of "sponsorship" of a given weapons acquisition may very well determine whether or not the system eventually becomes part of the nation's arsenal, regardless of the actual need or degree of problems encountered in the development and acquisition. The study authors, therefore, supported the "adoption of a set of 'rational' criteria by which to judge system success."[2]

THESIS OBJECTIVES

Improving the results of defense systems acquisition depends on learning from past mistakes and past successes. This requires consistent evaluation of project results with as much objectivity as possible.

The purpose of this thesis is to investigate the possibility of such a system of evaluation of the degree of success in naval ship acquisition. The objectives then are to determine for naval ship acquisitions a criterion for success and investigate the feasibility and alternatives for such a system.

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[1] Footnotes and references are listed at the ends of the chapters.

THE COMPLEXITY OF THE HARDWARE

Articles on naval ship acquisition usually begin with acknowledgment that major defense weapons systems are the most technically complex of any in existence. Perhaps the most complex of weapons systems are naval ships.

Ships are the largest mobile objects on Earth and naval vessels represent an integration of a myriad of major and minor interlocking systems of which many are extremely complex in their own right. A nuclear powered aircraft carrier is over 1100 feet long, displaces over 90,000 tons, and is propelled at speeds in excess of 30 knots by over 200,000 shaft horsepower. It is an airport with a capacity of 100 or more jet aircraft. Additionally, it is a self contained city with a population of 5,000 to 6,000 people. Its multi-reactor nuclear plant, various electronic systems and aircraft launching and recovery systems take years to design and prove before they are ready for installation.

THE COMPLEXITY OF THE PROBLEM

The complexity of the hardware in question is perhaps only matched by the complexity of the bureaucracy and process concerned with the acquisition of the hardware. In World War II, the entire Navy Department in Washington, D.C, charged with directing a war effort involving at the

peak of the war about 50,000 ships, consisted of about 200 people. Today there are in excess of 20,000 in the Washington, D.C., metropolitan area employed by the Navy. The active fleet today consists of less than 500 ships.

It commonly takes ten to twelve years to conceive, develop, design and construct a new U.S. Navy ship class. The problems of long range fiscal and engineering forecasting and planning in an unstable political and economic environment; and in the face of rapid technological advances, can be "mind boggling" as one Ship Acquisition Project Manager observed to the author.

THESIS OVERVIEW

The first chapter of the thesis is concerned with the three rather distinct strategies employed in defense systems acquisition since World War II. Though certainly not a complete treatment, the reader should gain from Chapter I considerable background information about the naval ship (and other weapon systems) acquisition process and structure. The major emphasis is on several new systems and policies which have been formulated during the past five or six years. The reader interested in a more complete analysis of the defense weapons acquisition process, particularly during the 1960's, is referred to the recent and excellent book <u>Arming America</u> by J. Ronald Fox.[3]

Chapter II is concerned with the case for a comprehensive, consistent evaluation system for naval ships. The problem of acquisition projects outliving acquisition policies and strategies is discussed. Then, the existing over-emphasis on "short-term" goal achievement, and the reasons for that over-emphasis, at the expense of longer term, strategic goals, is investigated.

It is concluded in Chapter II that a comprehensive evaluation system could help shift the balance of goal emphasis as well as fill the need for a centralized, complete historical record and data bank for ship acquisitions. A position is taken against use of the system for personnel performance evaluation.

Chapter III begins with noting that relevancy, objectivity and feasibility are desirable traits of a success evaluation system, but that total objectivity (requiring relevant, strictly quantitative criteria) is unobtainable in a feasible evaluation system for such a complex system.

The specification of goals and establishment of their relative priorities from the need requirements are noted as being prerequisites to the evaluation system. A definition of success is also required and a definition preference for naval ship acquisitions is offered.

The remainder of Chapter III is devoted to developing sets of criteria for the three major goal areas: performance,

cost and schedule. Finally, two different approaches to combining the individual criteria so that an overall assessment of success is possible are discussed.

A manual evaluation model is outlined and the reasons for adopting such a "low resource requirement" approach are offered. The scheme is similar to those utilized by acquisition projects for evaluating contractor bid proposals.

A framework for the development of a much more sophisticated, computerized simulation model is presented as an alternative to the manual model. This approach requires more resources to develop and use, but offers the possibility of a more accurate and objective model as more of the complex interdependencies of an acquisition can be accounted for and probabilistic criteria can be fully utilized.

The final conclusions and recommendations include

a) the success evaluation system outlined in the thesis is imperfect but preferable to the current situation (i.e. no long term structured system at all),

b) more work needs to be done in constructing evaluation criteria and in implementing existing and planned systems upon which the proposed evaluation system is built,

and,

c) the further specification and trial implementation of the proposed system of success evaluation is recommended.

NOTES TO THE INTRODUCTION

1. J. A. Dallen, Jr., L. C. Merkl, and R. J. Zlatoper, Managing the Weapon Systems Acquisition Process - A Case Study of the Main Battle Tank - 70, unpublished Masters of Science Thesis (Cambridge, Massachusetts, Sloan School of Management, M.I.T., 1975).

2. Ibid.

3. J. Ronald Fox, Arming America: How the U.S. Buys Weapons, (Boston, Division of Reasearch, Harvard Business School, 1974).

CHAPTER I

AN OVERVIEW OF POST WWII U.S. NAVAL SHIP ACQUISITION

INTRODUCTION

A brief overview of the structure and process of naval ship acquisition in the United States since World War II is presented in this chapter. Three rather distinct periods are indetifiable - the "Conventional" Period (until the early 1960's), the "Concept Formulation/Contract Definition" or "Total Package Procurement" Period (also called the "McNamara" Period after the then Secretary of Defense Robert S. McNamara) which began in the early 1960's and ended about 1969, and the "Current" Period. The major policies and characteristics of the three periods differ considerably, but it is not always possible to categorize a particular ship acquisition project as being a result of the policies of any one particular period. For example, the nuclear powered aircraft carrier project (the NIMITZ class of ships) was conceived during the Conventional Period, continued through the Concept Formulation/Contract Definition Period, and remains an ongoing project. The project has characteristics of all three policy periods. The ships were designed primarily by the Navy ("in house") with the aid of a design agent, typical of the Con-

ventional and Current Periods. The three (or four) ships of the class are being constructed under a multi-ship, multi-year contract, a significant aspect of the Concept Formulation/Contract Definition Period which has been continued.

Thus as the different periods are described, it should be remembered that ship projects are long (often ten to twelve years) and often transcend major acquisition policy shifts. Additionally, like any large bureaucracy, new policies and strategies from top management (the Secretary of Defense) often do not take effect at the working level (the projects) for two or three years, if at all.

THE BASIC PROCESS

Although policies and the organizational structure for designing and acquiring ships for the U.S. Navy have changed over the years, the basic process remains much the same. Also, though differing in details and nomenclature, the acquisition of ships is similar to the acquisition of other major defense systems. A need is identified; a requirement based on that need is established; a weapon system is selected, developed, designed and constructed to fill the requirement. Sometimes technological breakthroughs motivate a new acquisition (termed "technology push") but attempts are made to ensure that a legitimate need exists

prior to development and construction of the system.

The Navy and the other services are charged with "identifying needs and defining, developing and producing systems to satisfy those needs."[1] Establishing overall acquisition policy, passing on the validity of needs, and monitoring the performance of the services in carrying out the policy is the purview of the Office of the Secretary of Defense.[2]

National defense policies and objectives are provided by the Secretary of Defense and translated by the Joint Chiefs of Staff into military policies and objectives. Planning and programming by the services is keyed to these strategic objectives. Evaluation of the Joint Chiefs of Staff guidance can lead to research and development objectives formulation by the services to satisfy deficiencies in their capabilities to perform their respective assigned missions and roles.[3] The Program Objectives Memorandum is the budget for this effort. Later, Program Objectives Memoranda will contain the weapons systems which emerge from the research and development efforts.[4]

The Program Objectives Memoranda are part of the Department of Defense Planning-Programming-Budgeting System (PPBS). Funding for weapons systems is obtained through the PPBS. However, a series of approvals by intra-service councils

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[1] Notes are listed at the end of each chapter.

and the top level Defense Systems Acquisition Review Council is currently also required before a new weapons system is constructed. The role of the Defense System Acquisition Review Council will be discussed later in the chapter.

THE CONVENTIONAL PERIOD

At the end of World War II the U.S. Navy had 50,000 ships and there were 50 private and public shipyards working at or near capacity. Much of the fleet was "mothballed" (retired from active service) at the end of the war and production virtually ceased at the shipyards. During the Korean conflict most of the required ships were reactivated from the "mothball fleet". It was not until 1952 that the first significant new shipbuilding since World War II - 31 major ships - was directed.[5]

The major policies and practices were characterized by an iterative design process accomplished by the Navy "in house" or by an independent design agent up to and including a complete construction bid package, little documentation, major emphasis on ship performance, the splitting of the production contracts between two or more shipbuilders, and little involvement by the Office of the Secretary of Defense. The acquisition process was basically decentralized to the service level.

Initially, the entire design and procurement effort would be coordinated by a few individuals. They relied almost completely on the functional organizations to perform the necessary design and acquisition work required. Different self-contained organizations would be responsible for various systems on the ship. The "Gun Club" (Bureau of Ordnance) was responsible for weapons for example. Later, starting with the Polaris and other ballistic missile programs, the trend was towards project manager type organizations with varying degrees of self containment.

The reasons for spreading the production contracts between several shipbuilders are not known for certain but probably included the desires for rapid delivery of the ship class and preservation of the production base of the shipyards. Alternatively, the primary reason may have simply been regional political/economic pressures.

As depicted in Figure 1-1[6], the "Conventional" approach typically consisted of "in-house" talent formulating a ship concept. This activity included cost and feasibility studies and advance research and development as necessary. Assuming budgetary approval, increasingly refined and detailed design stages, termed "Preliminary Design" and "Contract Design" followed. The approach was basically evolutionary and utilized minimal systems analysis techniques.[7]

COMPARISON OF THE DEVELOPMENT SEQUENCE OF THE NAVY'S

SHIP ACQUISITION METHODS

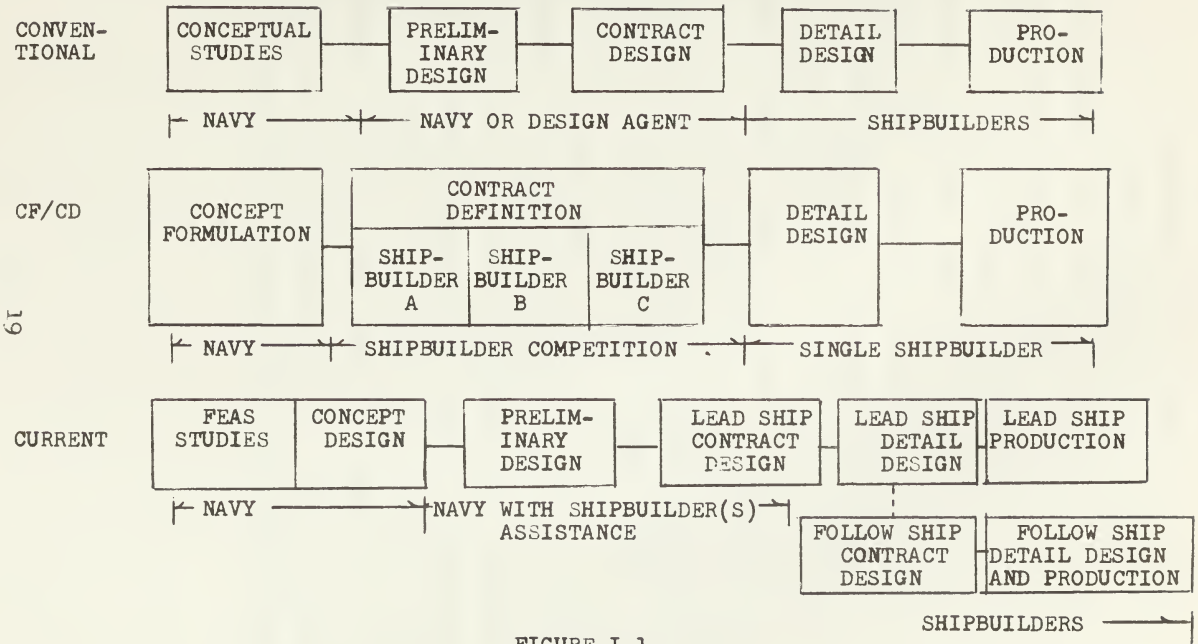

FIGURE I-1

The resulting product was a complete bid package, including complete contract plans and specification. The basic bid package could result in any number of procurement contracts. Lead ships (the first of a class) were often constructed in Navy shipyards. The amphibious ships LPD 7 through 15 were built under four separate contracts by two shipbuilders. Exclusive of the costs of changes to the contract, these ships were delivered to the Navy at an average 125% of the initial contract price (fixed price) and an average 27 months behind schedule.[8] Escalation due to inflation and claims against the government by the contractors accounted for most of the average 25% cost overruns.

The above results became increasingly typical. Low or negative profit performance by the contractors is thought to have precipitated many of the claims. The basis of contention in the claims was usually a dispute over interpretation of the often complex and detailed contract specifications. Additionally, production facilities were becoming antiquated and uncompetitive in the world market. Support of the ships was costly and often inadequate due to a lack of standardization between ships of a given class and between classes of ships.

THE CONCEPT FORMULATION/CONTRACT DEFINITION TOTAL PACKAGE PROCUREMENT PERIOD

A radically different approach to weapons design and acquisition was formulated in the early 1960's by the Office of the Secretary of Defense under Robert S. McNamara. The new approach centralized major decision making authority to the Office of the Secretary of Defense. Objectives were[9]

a) optimization of cost effectiveness by using systems analysis techniques,

b) reduction or elimination of contractor claims against the government by using contractor prepared performance oriented specifications vice government imposed detailed specifications,

c) reduction of cost overruns by transferring financial risk to the contractors for the design and acquisition phases through the use of fixed price contracts,

d) significant capitalization increases in shipbuilding facilities by using multi-ship, multi-year contract awards to a single shipbuilder that were expected to provide long term financial security enabling large scale capitalization and force expansion of facilities due to delivery schedule demands,

e) reduce unique systems and subsystems proliferation resulting from split production contracts,

f) introduce producability and innovation into the designs by having the production contractor design the system,

g) lower acquisition costs by taking advantage of the "Learning Curve" effect through single producer serial production (The "Learning Curve" had long been thought not to apply to shipbuilding but several studies conducted during the 1950's and 1960's indicated otherwise.),

and,

h) arrive at more accurate total cost estimates and reduce poor ship support by making the contractor responsible for all on board systems, crew training, initial repair parts, and support facilities. (This policy is known as "Total Package Procurement". Strictly speaking neither of the Navy acquisitions being acquired under Concept Formulation/Contract Definition policies are "Total Package Procurement" as there is government furnished equipment involved.)

A project manager type organization was directed for all major programs[10]. As outlined in Figure I-1, the services would still conduct advanced research and development and identify the desired performance characteristics of the new weapon system during the Concept Formulation stage. Assuming approval by the Secretary of Defense, a Contract Definition period would follow. A "Request for Proposal"

was prepared by the service and issued to selected shipbuilders(when more than one were thought capable) to prepare design analyses based on the specified performance characteristics. The Request for Proposal contained both mandatory and desirable performance specifications and were supposed to "encourage alternatives and stimulate initiative and creativity by the contractors".[11]

After evaluation of the proposals by the service, normally two or more contractors were given fixed price contracts to develop a complete shipbuilding proposal. Required in these proposals were contract plans and specifications, detailed construction plans, management plans and a complete analysis of the Life Cycle Costs.[12] Life Cycle Costs meant the total costs of acquisition and ownership - development, production, deployment, operation and maintenance.[13]

Total system tradeoffs were encouraged "to obtain, within the mission and performance envelopes, an optimum balance between total cost, schedule, and operational effectiveness for the system". Operational effectiveness was defined to include "pure" performance, reliability, maintainability and all other factors which affected the effectiveness of the new system. The system was defined to include the required facilities, personnel, data, training equipment as well as the the hardware itself.[14]

No longer than six months was allowed for the Contract Definition phase. This was followed by a Source Selection process during which a detailed analysis of the proposals was conducted by the procuring service. Negotiation was conducted with one or more of the contractors and transfusion of parts of one proposal into another was permitted. At the end of the evaluation period a recommendation was sent to the Office of the Secretary of Defense to award a multi-year, multi-ship procurement contract to the contractor with the best proposal, to conduct further Contract Definition, or to defer or abandon the effort (unlikely). The single contract awarded was fixed price, with or without incentive clauses.

The Navy conducted three Concept Formulation/Contract Definition ship competitions. The Fast Deployment Logistics Ship (FDL class) was not funded by Congress. The Amphibious Helicopter Assault ships (LHA class) and the SPRUANCE class destroyers (DD-963 class) are currently under construction. Litton Industries won all three competitions.

CONCEPT FORMULATION/CONTRACT DEFINITION RESULTS

"Frankly gentlemen, in defense procurement, we have a real mess on our hands."

The Honorable David Packard
Deputy Secretary of Defense, 1970

It is too early to evaluate the final results of the LHA and DD-963 ship acquisitions. The USS SPRUANCE (DD-963)

is the first ship delivered under either contract and was accepted by the Navy in 1975. However, the acquisitions have been beset by much the same problems that have characterized defense weapons systems procurement the last two decades - acquisition cost and schedule overruns of large proportions. This is particularly true of the first of the contracts, the LHA class. The first LHA is yet to be delivered and is several years behind the original schedule. A large claim against the government by Litton over the contract is pending and the contract has already been renegotiated (upwards in price and longer delivery times).

By the late 1960's, cost and schedule overruns and performance shortfalls of new major weapons systems were daily newspaper fare. In 1971 the Assistant Secretary of Defense for Financial Management (Comptroller) conducted a survey of 35 major development and production programs.[16] Only two of the programs were found to be on, or ahead of, schedule. That same year the General Accounting Office made a survey of 61 weapon systems and found that cost estimates for them had increased $33.4 billion over the initial estimates.[17] Contractor costs soared and profits plummeted. Huge cost and schedule problems in the C-5A aircraft were overshadowed in 1971 when cracks developed in the engine mountings.[18] The term "contractor bailout" became a household word as one producer after another threatened to cease production unless relief from the fixed price contracts was provided.

By 1970 a number of studies had found serious flaws in the management of the weapons acquisition process. The President's Blue Ribbon Panel, The National Security Industrial Association, the Defense Science Board Task Force on Research and Development Management, the Aerospace Industries Association, and the General Accounting Office conducted studies which all sounded very much the same theme. A March 1970 Logistics Management Institute report summarized the most common criticisms as follows:[19]

> "<u>First</u> is the observation that the weapons acquisition process apparently is out of control. Initial time and cost estimates - and even updated estimates - cannot be depended upon. Mandatory engineering changes arise continually throughout the process. Management information and control systems do not identify impending problems in time for preventive action to be taken.
>
> <u>Second</u> is the claim that bargaining positions are unbalanced; first one side, the the other has the advantage. The theory of countervailing pressures acting to produce fair and realistic contract terms does not hold. With emphasis on economies of scale and series production there are only a small number of

weapon systems competitions each year and prospective contractors believe that their very existence may be jeopardized by failure to win. Hence the Department of Defense (DOD) is in the dominant position and can compel an unreasonable bargain. Following award of the contract, the DOD, committed to the timely success of the program, is in the weaker position as the sole source contractor negotiates for contract changes, product acceptance, and follow-on business. Third is that incentives both for efficient operation and for candor about expectations are lacking. Heavy reliance on historical costs in pricing, lack of adequate consideration of capital required in negotiating profit rates, and the high risk of low future utilization of contractor owned facilities impede investment and modernization of plant. The hazard to program survival, of high cost, long duration, or looming technical difficulties, as each program competes with others in and out of the DOD, motivates extreme optimism by DOD and contractor personnel alike.

> Fourth are allegations of confusion, connivance, and deception by the DOD-contractor combination. Close cooperation and common interest are held in contrast to the arm's length relationship preferred by much of regulation and policy. Policy notwithstanding, the military departments receive advice and assistance from prospective contractors in preparation of Requests for Proposals. Contractors receive aid from government personnel in performance of contracts. Contracts fail as instruments of control."

On May 28, 1970, Deputy Secretary of Defense David Packard issued a memorandum which stated that the Total Package Procurement approach to developing and acquiring major weapon systems was unsatisfactory and that a new policy would soon be established.[20] The Navy was still years away from delivery of its first ship procured under the cancelled policy. Whether or not the long term objectives of the Concept Formulation/Contract Definition/Total Package Procurement Period will be achieved for the Navy ships remains to be seen. It is a fact that the sole source multi-year contracts resulted in the construction by Litton of a new shipyard at Pascagoula, Mississippi. Interviews

conducted by the author with project personnel brought out the beliefs of several that the policies were never given a fair chance. This resulted from the failures of the F-111 and C-5A aircraft procurements in particular and the problems that Litton was experiencing in developing an adequate design and production force and in making the new facility operationally efficient.

THE CURRENT PERIOD

The major policies and trends of new ship acquisition since the demise of Concept Formulation/Contract Definition include

a) emphasis on constrained design ("Design-to-Cost"),

b) emphasis on proven hardware ("Fly-before-you-Buy"),

c) required review and approval to proceed by the Defense Systems Acquisition Review Council at key milestones,

d) a prohibition against Total Package Procurement (linkage of system development and production under a single contract),

e) improvement of the quality and validity of cost estimates,

f) flexibility in contract type and liberalization of contract escalation (due to inflation) clauses,

g) use of contractor aided "in-house" ship design,

and,

h) tailoring of acquisition approaches to each project.

"DESIGN-TO-COST"

The cancellation of the key top level policy directive[21] for the Concept Formulation/Contract Definition period in 1970 left a guidance void that was not formally filled until the issuance of Department of Defense Directive 5000.1, "Acquisition of Major Defense Systems", on July 13, 1971. It was during this same period that then Chief of Naval Operations Zumwalt directed the rapid development of a large class of austere, relatively inexpensive Guided Missile Frigates (FFG class, formerly the Patrol Frigate or PF class) to bolster the size of the rapidly diminishing fleet.[22]

After a year of feasibility studies, Admiral Zumwalt directed that the design would not violate constraints which were set on the average "follow" (after the first) ship acquisition cost and fully loaded ship displacement.[23] He later added a third constraint on the maximum number of accomodations on the ship.[24] Performance capability above the minimum specified was to be traded off to stay within the constraints. This method of ship design, commonly termed "Design-to-Cost", was revolutionary to the Navy, but is common in industry for new product development.

A major program consideration of current acquisition policy is that "discrete cost elements (e.g. unit production cost, operating and support cost) shall be translated into "design to" requirements".[25] In October 1973 the major services' material commands jointly issued a "Joint Design-to-Cost Guide".[26] This directive requires that "Design-to-Cost be used for major systems except that

a) "Major weapons systems which for reasons of national security necessarily push the state-of-the-art should stress performance. In such cases, unit production cost goals will be applied and tracked but will be subordinate to performance goals."

and,

b) "Major weapons systems where the assessed need is sufficiently urgent should stress the schedule. In such cases, unit production cost goals will be applied and tracked but will be subordinate to schedule goals."

Implementation of the above exceptions requires Secretary of Defense approval. The TRIDENT strategic ballistic missile submarine class is such an example.

Historically, performance requirements for new ships had been dictated by the Chief of Naval Operations to the material command in brief "single sheet characteristics".[28] These were used by the material command "to develop preliminary designs and cost estimates leading to more detailed characteristics statements, and ultimately to procurement

specifications."[29] Costs were considered but were usually secondary to maximizing performance. As "Design-to-Cost" elevated the importance of acquisition cost to the same level as performance in the design process, a new iterative performance-cost tradeoff dialogue between the customer (Chief of Naval Operations) and producer (Chief of Naval Material) organizations was required. "Top Level Requirements and Top Level Specifications for the development of naval ships", Chief of Naval Operations Instruction 9010.300, was issued early in 1974. It details a procedure which provides for a working group to develop the performance parameters for a baseline ship which will meet the established mission requirements. The group also specifies allowable variations in performance parameters and alternative system selections for the ship class.[30]

After a period of Feasibility Studies during which the impact of the alternative performance parameters and systems selections are evaluated, the Chief of Naval Operations organization starts preparation of a Draft Top Level Requirements document. This document is revised as the Naval Material Command (parent command of the Naval Sea Systems Command for whom acquisition projects directly work) develops a conceptual design for the ship class and provides cost and design information to the Chief of Naval Operations. Assuming approval by the Chief of Naval Operations to proceed

with a selected design, a "Conceptual Baseline" and a "Cost Goal" for the average follow ship acquisition costs are presented to the Defense Systems Acquisition Review Council which is composed of high level officials in the Office of the Secretary of Defense. If council and Secretary of Defense approval is given to proceed into "Preliminary Design", a Draft Top Level Specifications document is started by the Naval Material Command (actually the acquisition project). This companion document to the Top Level Requirements "translates the Top Level Requirements into a physical ship description".[31] The contents of the two documents are discussed in Chapter III. The process phasing is presented graphically in Figure I-2.[32]

The Naval Sea Systems Command recently issued a "Design-to-Cost Guide for Ship Acquisition"[33]. This directive specifies that the procedure of "Desgin-to-Cost" will be utilized for all ship acquisitions for which a Top Level Requirements document is prepared. It exempts, as do most ship acquisition directives, nuclear propulsion plants and nuclear support facilities under the cognizance of Admiral Hyman G. Rickover, Director of Naval Reactors. The Chief of Naval Operations has stated that a Top Level Requirements and Top Level Specifications will be developed for "all new ship designs except fleet ballistic missile submarines."[34]

TOP LEVEL REQUIREMENTS/TOP LEVEL SPECIFICATIONS
DEVELOPMENT SEQUENCE AND
DEFENSE SYSTEMS ACQUISITION REVIEW COUNCIL (DSARC) PRESENTATIONS

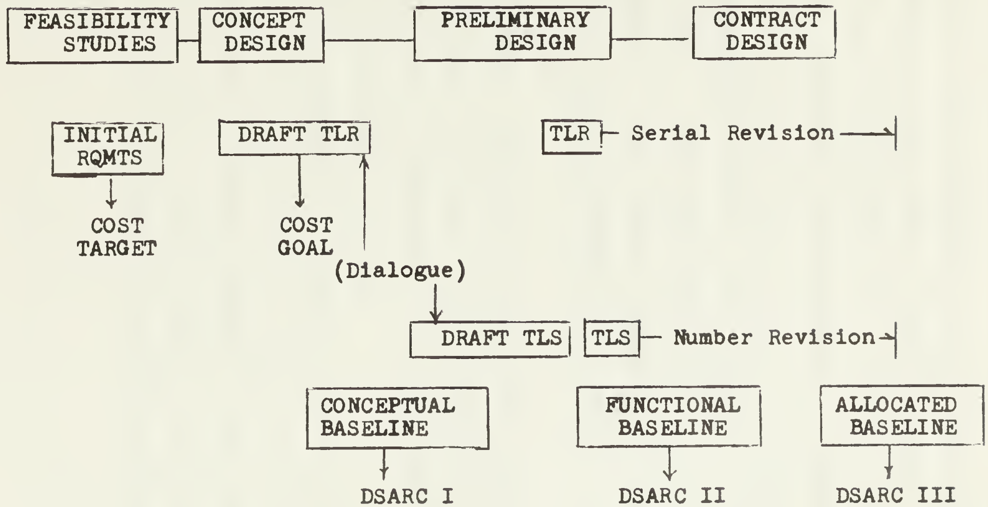

FIGURE I-2

"FLY-BEFORE-YOU-BUY"

It had been intended that before permission to proceed into Contract Definition would be granted, "primarily engineering rather than experimental effort" would be required and the technology needed would be "well in hand".[34] However the large performance shortfalls, schedule delays and cost increases referred to in the previous section were at least partially a result of overly optimistic estimates of ultimate system capabilities and the time required to design and perfect them.[36] There had been a great deal of reliance on "paper studies" rather than on actual performance demonstrations. Thus, a major program consideration of the Current Period is that[37]

> "Programs shall be structured and resources allocated to ensure that the demonstration of actual achievement of program objectives is the pacing function."

A supporting Department of Defense directive was issued in January of 1973 to establish test and evaluation policy for the acquisition of defense systems.[38] This policy emphasizes

a) the need to conduct test and evaluation as early as possible and to continue it as long as necessary to eliminate risks,

and,

b) acquisition schedules will be based on the completion of test and evaluation milestones prior to key decision points (Defense Systems Acquisition Review Council approval points. See Figure I-2.)

The key element which has grown from recognition of the need for increased test and evaluation during the acquisition process has been prototyping. This is commonly known as the "Fly-before-you-Buy" policy and is currently being used in the acquisition of new aircraft and in the Navy's surface effect ships and NATO patrol hydrofoil programs. It is not feasible, however, to build and evaluate prototypes prior to beginning follow ship design and production for large ships. The time required, small numbers involved (one or two in some cases) and threat of obsolescence dictate a modified "Fly-before-you-Buy" approach.

The Guided Missile Frigate Program developed a plan which provided for

a) early construction of Land Based Test Sites for complete propulsion and combat systems

and,

b) a delay of two years between construction contract awards for the lead and follow ships.[39]

This plan permits testing of the two major "high risk" subsystems prior to installation on the lead (first) ship and time to incorporate changes resulting from the entire test

and evaluation program into the design of the follow ships. The Land Based Test Sites will also be used for crew training.

THE DEFENSE SYSTEMS ACQUISITION REVIEW COUNCIL

The Defense Systems Acquisition Review Council (DSARC) was established in the Office of the Secretary of Defense by Deputy Secretary of Defense David Packard in May, 1969.[40] The purpose of the council reviews is to evaluate thoroughly the status of major defense systems acquisition projects at three critical milestones which generally occur for ship acquisitions as indicated in Figure I-2.

Formal documentation for the DSARC reviews and decisions is provided by the project prepared Decision Coordinating Paper (formerly Development Concept Paper). It is a summary document of not more than twenty pages that records the primary information on a program including the thresholds, issues and risks, need, the alternatives, the reviews, rationale for the decision, and affordability. When signed by the Secretary of Defense, it is the authority for the service to proceed with the program (or whatever action the Secretary of Defense directs). His decision sets the limits of authority (thresholds) within which the project is obligated to stay.[41]

A long series of intra-service briefings and reviews is generally required of an acquisition project prior to a DSARC presentation.

COST ESTIMATING

By 1970, the credibility of the Department of Defense concerning system acquisition cost estimates was extremely low. When the new acquisition policy directive was issued by Mr. Packard in 1971, it directed that "Traceability of estimates and costing factors ...... be maintained". In December, 1971, Mr. Packard issued a memorandum requiring incorporation of independent (from program proponents) parametric cost analysis in Defense Systems Acquisition Review Council presentations.[43]

Parametric cost estimates are "based on quantified relationships between the cost and physical performance characteristics of past systems for initial program decisions".[44] Engineering cost estimates (normally used by acquisition projects) are based on detailed design information. Cost Information Reports (now Contractor Cost Data Reports) submission requirements have been written into production contracts in order to build a data base from which to develop parametric cost estimating relationships.[45]

Fox discusses a third estimating alternative for use in preparing contract negotiation objectives.[46] This technique,

known as "should cost" analysis had its beginnings in the civilian economy and was developed in the early 1960's for the Department of Defense under the direction of then Defense Comptroller Robert N. Anthony. Fox describes the process as follows

> "This technique begins with an in depth analysis of a contractor's management, cost estimating, and production practices to identify and measure the effects of poor performance. From a baseline developed by eliminating costs resulting from inefficiencies, projections are made for the current procurement. The objective is to foster improved industrial practices by setting realistic contract prices."

Under the approach, a team of experts in engineering, pricing, auditing, procurement and management spend several weeks at the contractor's facility. They review in detail the company's operations and procedures. Standard industrial engineering techniques are used to uncover inefficiencies.

Fox cites several examples of should-cost analyses successes in reducing costs. He also notes that it is difficult to achieve high quality, factual investigations and that there had been considerable resistance from within contractor organizations and from within the Department of Defense.

A Cost Analysis Improvement Group (CAIG) was established

in January 1972 in the Office of the Secretary of Defense "to review the estimates presented and to develop uniform criteria to be used......".[47] By the time a permanent charter for the CAIG was issued in 1973, its responsibilities had grown to include, interalia, identification of where efforts are needed to improve the cost estimating capabilities of the services.[48] Improvement of the validity and tracking of cost estimates has recently been addressed by the Secretary of the Navy, Chief of Naval Operations, and Chief of Naval Material directives.[49] None of the directives refer to the "should-cost" technique of cost estimating. A discussion of the provisions of the directives is contained in Chapter III. Figure I-3 shows the responsibilities for ship cost estimating and the cost estimating organizational relationships within the Navy.[50]

CONTRACTOR COST AND SCHEDULE CONTROL

As more and more contractors failed to perform under the Concept Formulation/Contract Definition Period fixed price contracts, the need for increased government engagement with the contractors was realized. The fixed price contracts and lack of government involvement in the design supposedly transferred any financial risks from the government to the contractor and thus the role of the acquisition projects was basically that of monitoring, with little control leverage.

DEPARTMENT OF THE NAVY
SHIP COST ESTIMATING/ANALYSIS RESPONSIBILITIES

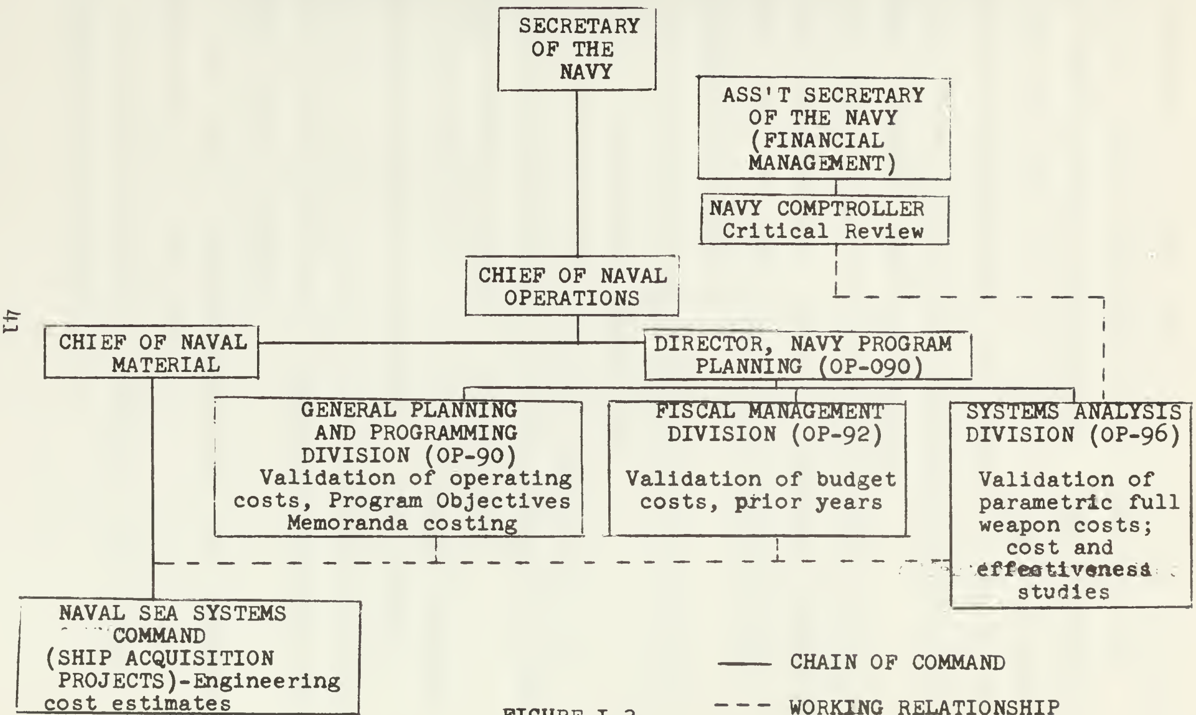

FIGURE I-3

The current top level acquisition policy directive specifies that "Contract type shall be consistent with all program characteristics including risk." Also stipulated is that "Cost type prime and subcontracts are preferred where substantial development effort is involved."[51] The use of cost type contracts opens up the possibility of increased government engagement with the contractor.

Apart from the lack of governmental control leverage resulting from fixed price contracts, attempts at effective contractor cost and schedule control by the projects has historically been hampered by[52]

a) a reluctance of the contractors to share what it considers to be proprietary information,

b)the preoccupation of project managers with the annual funding approval process and the continuity of funds flow (funds control) as opposed to cost control,

c) the proliferation of various information and cost control systems imposed on contractors by the different services and projects (validity of the information was often lost in the translation from the contractor's system to the government imposed system(s)),

d) the lack of inclusion in the reporting systems of the budgeted value of work performed,

e) improper allocation of contractor costs between overhead(indirect) and direct costs,

f) inability of the project personnel to evaluate the detailed information they require of the contractor, and lack of correspondence between reported data and the contractor's own data,

g) retroactive changing of financial plans to conform to work performed to date (the "rubber baseline")

and,

h) contractor use of nonintegrated work breakdown structures and nonintegrated charts of cost accounts (sum of budget dollars for work at one level may exceed budget at next higher level).

In a survey conducted during the 1960's, Fox found that most program managers were satisfied if their funds control reports indicated that funds were being expended at the planned monthly rate and their PERT networks reports[53] showed no significant schedule slippage.[54] Schedule network reporting based on starts rather than completion, untimely or inaccurate reporting, and the lack of performance of scheduled noncritical path work all served to build in cost overruns which often went undiscovered until it was too late to take any meaningful cost or schedule control action.

In 1967 the Department of Defense issued a directive title "Performance Measurement for Selected Acquisitions".[55] The system is summarized as follows[56]

"Part One of the program requires that contractors

> use internal planning and control systems that meet minimum government criteria. These criteria are called the 'Cost and Schedule Control Systems Criteria' (CSCSC).
>
> Part Two of the program requires that contractors regularly submit Cost Performance Reports which contain information on the budgeted value of work performed to date. (The criteria themselves do not require the submission of any reports to the government, but specify the reporting capabilities which contractors' internal systems must have, and the types of data which the systems should be able to produce.) The contractor is free to design his internal planning and control systems to correspond to the manner in which he organizes his work units and assigns responsibility for performing work."

An important concept in the reporting criteria is the contract cost status reports must be based strictly on the number of jobs completed to date.[57]

Five years after the CSCSC had been developed, only 16 defense contractors had been certified as complying with the criteria. The Navy was singled out by the Senate Armed Service Committee as being particularly slow in implementing the new system.[58] In 1971 an additional twenty contractors complied with the criteria and all three services were act-

ively implementing the program and training personnel in its use.[59]

CURRENT PERIOD RESULTS

It is certainly too early to make any factual observations about the results achieved by the reforms instituted since 1969-70 in the ship acquisition process. The Guided Missile Frigate program, as indicated, pioneered many of these reforms in the Navy. In addition to those aspects of the Guided Missile Frigate acquisition plan already discussed, a key element of the plan was to select a "lead" and a "secondary" contractor early in the design effort. The function of the "lead" shipbuilder was to assist in the "in-house" design effort and ultimately to build the first ship under a "cost plus" type contract. The purpose of this was to introduce producability into the design, to promote design familiarity and acceptance of performance responsibility by the contractor, and to reduce development time.[60]

The "secondary" shipbuilder was involved to prevent the introduction of producability bias by the "lead" shipbuilder which would result in unfair advantage when bidding on the follow ship contracts and to provide a "fallback" position in case lead ship contract negotiations turned sour. When the first increment follow ships fixed price contract bids were received in late summer 1975, the Navy was dismayed to

receive bids from only two contractors - the designated "lead" and "secondary" contractors. Moreover, the bid prices were well in excess of the "Design-to-Cost" constraint, - reportedly as much as 60% over. It can be speculated that the lack of participation in the bidding by other shipbuild - ers and the high bids submitted were due to one or more of the following reasons

a) shipyard loading by other (primarily merchant ship) contracts,

b) the poor profits and losses experience on previous contracts,

c) a reluctance to accept the required engagement by the government in the contractor's procedures and operations,

d) fear that the escalation provided for in the contracts for inflation will be insufficient, as it has been in the past,

and,

e) the Navy's cost estimate was far too low.

Whether or not the current difficulties in the Guided Missile Frigate program are a result of past project difficulties or an indication of the failures of the new reforms is indeterminable at the present time. How many Guided Missile Frigates (50 were originally planned) will ultimately be built, whether or not contractor's will accept the desired increased engagement by the government in "their affairs",

and the future of constrained ship design are all open to conjecture. The Navy's only other "Design-to-Cost" ship class to date, the DG Aegis, was cancelled and replaced by the nuclear powered Strike Cruiser (CSGN). Is is an "unconstrained design and one not indicative of the 'Design-to-Cost' concept."[61]

Chapter II will consider the case for a comprehensive and structured ship evaluation system.

CHAPTER I CONCLUSIONS AND SUMMARY

Three distinguishable periods of naval ship acquisition policy have occurred since World War II. The periods are referred to as the "Conventional", "Concept Formulation/ Contract Definition" or "Total Package Procurement", and the "Current".

The aprroaches have differed in the degree of centralization of control within the Department of Defense; contractor - government relationships; the degree of systems analysis; whether the design was accomplished by the government, private industry, or by both; and the types and numbers of control systems.

The objectives have remained basically the same: to deliver the ships needed for the nation's defense, when they are needed, and at an affordable, promised price. The visible results have also been similar - disappointing, to say the least.

NOTES TO CHAPTER I

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4. Ibid.

5. John D. Carpenter and Peter C. Finne, "Navy Ship Procurement", Naval Engineers Journal, Vol. 84, No. 6, December, 1972.

6. Adapted from an unpublished paper by Clark Graham, "The Navy's Approach to Ship Design and Acquisition".

7. Ibid.

8. Carpenter and Finne, op cit.

9. Ibid.

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11. Department of Defense Directive 3200.9, "Initiation of Engineering and Operational Systems Development", July 1, 1965.

12. Ibid.

13. Ibid.

14. Ibid.

15. Ibid.

16. J. Ronald Fox, Arming America: How the U.S. Buys Weapons, (Boston, Division of Research, Harvard Business School, 1974).

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20. Deputy Secretary of Defense Memorandum, "Policy Guidance on Major Weapons System Acquisition", May 28, 1970.

21. Department of Defense Directive 3200.9, op cit.

22. John W. Newcomb and Anthony R. DiTrapani, "The Patrol Frigate Program - A New Approach to Ship Design and Acquisition", Naval Engineers Journal, Vol. 85, No. 4, August, 1973.

23. Ibid.

24. Ibid.

25. Department of Defense Directive 5000.1, op cit.

26. Naval Material Command publication P5242, "Joint Design-to-Cost Guide", October 29, 1973.

27. Ibid.

28. Chief of Naval Operations Instruction 9010.300, "Top Level Requirements and Top Level Specifications for the development of naval ships", January 4, 1974.

29. Ibid.

30. Ibid.

31. Ibid.

32. Adapted from Commander, Naval Sea Systems Command Instruction 9060.1, "Top Level Specifications (TLS) for new ship design", May 6, 1975.

33. Commander, Naval Sea System Command Instruction (Draft) (unnumbered), "Design-to-Cost Guide for Ship Acquisition", undated.

34. Chief of Naval Operations Instruction 9010.300, op cit.

35. Department of Defense Directive 3200.9, op cit.

36. Fox, op cit.

37. Department of Defense Directive 5000.1, op cit.

38. Department of Defense Directive 5000.3, "Test and Evaluation", January 19, 1973.

39. Newcomb and DiTrapani, op cit.

40. Deputy Secretary of Defense Memorandum, "Establishment of a Defense Systems Acquisition Review Council", May 30, 1969.

41. Department of Defense Instruction (Draft) 5000.2, "The Decision Coordinating Paper (DCP) and the Defense Systems Acquisition Review Council (DSARC)", February 23, 1973.

42. Department of Defense Directive 5000.1, op cit.

43. Deputy Secretary of Defense Memorandum, "Use of Parametric Cost Estimates", December 7, 1971.

44. Gardiner L. Tucker, "The Role of Systems Analysis",

45. Chief of Naval Material Instruction 7000.23, "Contractor

Cost Data Reporting", December 9, 1974.

46. Fox, op cit.

47. Secretary of Defense Memorandum, "Cost Estimating for Major Defense Systems", January 25, 1972.

48. Department of Defense Directive 5000.4, "OSD Cost Analysis Improvement Group", June 13, 1973.

49. Secretary of the Navy Instruction 7000.19B, "Department of the Navy Cost Analysis Program", March 12, 1975. Chief of Naval Operations Instruction 7000.17, "Cost Analysis" January 2, 1973. Chief of Naval Material Instruction 7000.19, "Cost Analysis Program", February 21, 1973.

50. Chief of Naval Operations Instruction 7000.17, op cit.

51. Department of Defense Directive 5000.1, op cit.

52. Fox, op cit.

53. Program Evaluation and Review Technique is a schedule network analysis method which determines the "critical path" (critical path of key milestones). PERT reports were required of contractors by Department of Defense Directive 3200.9, op cit.

54. Fox, op cit.

55. Department of Defense Instruction 7000.2, "Performance Measurement for Selected Acquisitions", December 22, 1967, (revised and reissued April 25, 1972).

56. Fox, op cit.

57. Ibid.

58. U.S. Senate, Armed Service Committee, Report 92-359,

Authorizing Defense Appropriations for Fiscal Year 1972,

as reported in Fox, op cit.

59. Fox, op cit.

60. Newcomb and DiTrapani, op cit.

61. Clark Graham, op cit.

CHAPTER II

THE CASE FOR A NAVAL SHIP EVALUATION SYSTEM

INTRODUCTION

This chapter considers the major factors supporting establishment of a comprehensive ship evaluation system. These factors include the historically short lived acquisition policies (relative to project duration), over-emphasis on short term goal achievement, and the need for a ship acquisition life-cycle historical record and data bank.

It is concluded that successful establishment of a comprehensive evaluation system will result in a better basis than now exists for formulating high potential acquisition system improvements and some desirable increase in emphasis on longer term goal achievement. A danger in the evaluation system will be the tendency to use its results for personnel performance appraisal.

A BETTER BASIS FOR ACQUISITION SYSTEM CHANGES IS NEEDED

As discussed in Chapter I, defense system acquisition policies and strategies have been unstable relative to the considerable length of time required to develop and construct a new class of ships (often ten to twelve years). Three

major departures in acquisition policy occured in less time than it took to develop and procure the USS NIMITZ, the first in a new class of nuclear powered aircraft carriers. The primary emphasis in weapons system acquisition policy changed from maximum technical performance during the Conventional Period, to "cost effectiveness" over the life-cycle during Concept Formulation/Contract Definition, to achieving acceptable performance for the minimum acquisition cost during the Current Period. Although the NIMITZ may partially reflect parts of all these policies, the "die was cast" early in its development, under the Conventional Period policies.

The Navy is paying a large price for the adaptability and ease of conversion (to minimize life-cycle costs) designed into the new SPRUANCE class destroyers (DD-963 class) under construction by Litton. This was a keystone of the Concept Formulation/Contract Definition strategy. The new Guided Missile Frigate class, however, is a "tight" design with small margins (reservations for future systems weight and volume requirements). This is a direct result of the acquisition cost and displacement constraints placed on the design resulting from the Current Period policies.

It is easy to forget when judging a ship which policies were in effect when it was designed and constructed (and also what the acquisition environment was like). Without a formalized, consistent evaluation system which collects and

assesses data on the actual results of the acquisitions throughout the ships' life-cycles, the Navy will never know the degree of successes and failures realized under the various acquisition policies and strategies. Without this knowledge, changes to the acquisition system are reactionary and often little more than "shots in the dark".

INCREASED EMPHASIS ON LONG TERM GOAL ACHIEVEMENT IS NEEDED

Short term goals in ship acquisition include those concerned with acquisition cost and delivery schedule. Longer term goals include minimizing total life cycle costs and providing capability in the design to adapt successfully to new and unforseen mission requirements and to counter future threats. Both types of goals are important, depending on the requirements of the need. The realities of the political/economic environment strongly influence the selection of goals and their attainment, as does the need requirements. The following few sections will focus on the reasons for dominant emphasis on short term goals and why longer term goals may be more important.

SHORT TERM GOAL ATTAINMENT PRESSURES

There are a number of reasons why short term goals achievement receives more emphasis in ship acquisition than longer term goals achievement. Short term goals, generally

attainable during the acquisition phase, are more easily quantified and measured. The short tenure (relative to the development and acquisition time) of key participants increases the pressure to optimize short term goals. A typical project will have two or three different project managers. They are likely to achieve or fail promotion based on the results of the acquisition foreseeable during their tenure. One Ship Acquisition Project Manager interviewed by the author noted that "For a successful project in this building, bring it in within cost and on schedule. Unfortunately, the fleet will not see it that way."

By "cost" the project manager meant "acquisition cost", and "in this building" refers to the parent organization of the project, the Naval Sea Systems Command. The last line indicates the project manager's awareness that the operators are concerned with longer term goals. A senior Naval Material Command (parent organization of the Naval Sea Systems Command) executive recently prepared "lessons learned" from two troubled projects. He noted that

> "Our current reward system does not encourage special attention to that portion of the program which will occur 'down the pike' on a subsequent project manager's watch. Our reward system recognizes near term achievement. With the increased tour lengths of project managers, this problem has been partially alleviated."

The Concept Formulation/Contract Definition period policy

directive required minimum tour lengths of three years for project managers.[1] Recent emphasis has been towards tours of four or five years with relief occurring at major milestones.

The tenures of other key procurement participants are normally less than the project's life. Key officials in the Navy and the Department of Defense, military or civilian, rarely are in office more than three or four years. Few Congressmen, particularly Representatives, can afford to emphasize long term goal achievement at the expense of short term, visible results as a result of their frequent reelection requirements. Additionally, Congress does not presently have the capability to assess the long term results of acquisition programs. The end result is that many military and public officials who sponsor and approve the acquisition of new defense systems are not around to evaluate the program results.[2]

Economic Realities

The move away from minimizing life-cycle costs and towards tight control of acquisition costs by specifying acquisition cost constraints as design parameters was precipitated by

a) the monumental cost overruns of the 1960's,

b) diminishing real resources available for new acquisitions

and,

c) a rapidly aging and diminishing fleet.

A recent study of the Navy's acquisition system noted that[3]

"Changing national priorities have reduced the percentage of the Federal Budget now devoted to defense to the lowest point since 1946."

and,

"..........the U.S. Navy today possesses the lowest force level it has known since before 1950........."

Reporting and Control Systems Effects

Anthony observes that in business,[4]

"Management control systems tend to measure current performance, rather than long term performance. That is, they measure the profit earned this year, rather than the effect on future profits of actions taken this year."

There is certainly a directly analagous situation in the defense systems acquisition process. The Selected Acquisition Reports, submitted quarterly to Congress by major weapons projects, contain a lengthy analysis of variances from

acquisition cost estimates. The sections on technical performance estimate changes is brief and there is no provision for life cycle costs in the reports.[5]

Funding

New weapons systems are funded annually by Congress. The Shipbuilding and Conversion, Navy (SCN) account carries a five year obligation authority for the annual appropriations. This account, until recently, covered new ship development and production. Recently, funding of new ship development and construction of the lead ship of a class has been provided by the Research, Development, Testing and Evaluation (R,D,T&E) account. This budget category only authorizes a single year obligational authority. Long range planning is extremely difficult under such a short funding time horizon. Erratic congressional action on the yearly appropriations is not uncommon, and this compounds the problem and serves to emphasize short term goal achievement.

THE IMPORTANCE OF LONG TERM GOALS

The threat of obsolescence in new ships at the time they are delivered for service is real. The missions and threats they are designed to cope with may change dramatically during the long development and acquisition period. In the

average ship's thirty years service life, missions, threats and available systems will continue to change as a result of rapid strides in technology. Certainly the ultimately important test of ship performance is how it performs the missions it is called upon to perform, whenever that might be.

The cost to develop and acquire a new ship is typically only about one fifth of the total expenditures over the life cycle of the ship.[6] Over emphasis on the short term goal of minimum acquisition cost can not help but negatively impact the total life cycle cost. Increased automation in a ship results in smaller manning requirements, but the automation increases the acquisition cost. Larger manning requirements, however, significantly impact the operating costs both through increased ship size (as much as 750 cubic feet per man) and the dramatically increasing costs of wages and benefits. Another example concerns the long life, low maintenance coatings and materials becoming available which are costly to purchase but may favorably impact total life cycle cost. Chief of Naval Operations Zumwalt realized the severe impact on the increasingly limited Navy resources of the high operating and maintenance costs of the aging fleet. He embarked on a plan to eliminate rapidly many of the costly old ships in order to free funds for new ship construction.

In conclusion, ship acquisition long term goals (e.g.

minimum total life cycle costs and capability to adapt rapidly to new threats and missions) are important but the balance of pressures on the acquisition process are towards short term goal achievement. A consistent and comprehensive evaluation system, operable throughout the ship's life cycle, can help shift this balance by evaluating and making visible the degree of attainment of long term goals.

A COMPLETE HISTORICAL RECORD IS NEEDED

The recent effort to improve cost estimating within the Department of Defense (see Chapter I) by the use of comparative parametric cost estimates has been hampered by the lack of historical return costs of previous weapons acquisitions. Engineering cost estimates and actual design control are developed along the lines of a work breakdown structure in accordance with Military Standard 881, "Work Breakdown Structures for Defense Material Items".

However, the accrual accounting system established July 1, 1974, for the procurement appropriations uses a different cost category breakdown which does not correlate easily with the work breakdown structures used by the projects.[8] A recent effort to develop a cross referencing system between the design and engineering cost estimating work breakdown structures and the accounting system breakdown failed. An additional difficulty in building a return cost

historical data base is the previously discussed contractor reluctance to divulge actual costs.

The current increased emphasis on traceability of performance, cost and schedule estimates was noted in Chapter I. Historical records of the project are required to be maintained by the project staff but the records may or may not be available to new projects and are of varying formats and quality.

After the acquisition phase, a lot of cost and performance data is generated in different accounts and by different systems. There are at least a half dozen different cost accounts for the Navy which contain parts of the life cycle costs of ships. Life cycle costs such as those of maintenance, training and replenishment facilities and operations are not always identified with the ship classes receiving the support.

PERFORMANCE DATA

Currently during acquisition, the performance of a ship system is being demonstrated more rigorously than ever before. Actual hardware demonstrations are replacing paper estimates earlier in the process in many cases. At the end of the acquisition phase, complete ship trials are conducted by the Board of Inspection and Survey to assess the performance of the ships.

After acquisition, there are numerous sources of information about actual ship performance. In recent years, actual combat performance has been available. In peacetime, ship's undergo a constant series of inspections of various types. They participate in fleet training exercises, undergo ship "refresher training", and compete with other ships in their operating groups for coveted "Efficiency" awards which are based on the outcome of a series of standard exercises. The Board of Inspection and Survey and the Propulsion Examining Boards conduct periodic comprehensive inspections of material and operating readiness. Information about the reliability, maintainabiliy and performance of equipments is generated from the "3M" system of scheduled preventive maintenance and corrective maintenance reporting. Operational ships report the status of their capabilities to perform mission requirements through the Joint Chiefs of Staff Force Status and Identity Reports. Significant degradations due to equipment and system casualties or personnel deficiencies are reported using the "Naval Combat Readiness Criteria".[9]

From the above and other sources, pertinent data about the performance of the ships and their costs are generated. To the author's knowledge however, there is no concerted effort to collect and assimilate all the pertinent data and utilize it to evaluate the long term worth of the ships. Such a purpose would be served by a central evaluation system.

THE EVALUATION SYSTEM AND PERFORMANCE APPRAISAL

The evaluation system is not being proposed as a control system. Control systemsare short horizon oriented and there are sufficient and entirely adequate systems (see Chapter I) in existence to help manage the acquisition process and evaluate the cost effectiveness of goal achievement during the acquisition phase.[10]

There are several reasons why the evaluation system to be outlined in the next chapter should not be used for personnel performance appraisal. Personnel appraisal demands a degree of fairness and objectivity that will not be attainable in a system that is designed to evaluate the long term results of a process as complex and long lived as a ship acquisition. It may be true that the responsibility of management is to be fair to subordinates, not necessarily to design a personnel appraisal system that is completely fair and objective in itself.[11] However, as noted by Christensen, et al,[12]

> "By far the most important problem of measurement is that increased interest in the measurement of performance against standards brings increased danger that the executive evaluation program may encourage performance which detracts from rather than supports the overall strategy."

This tendency results in actions which are directed

towards optimizing the performance system results at the expense of the projects goals, particularly long term goals. The more quantitative and simplistic the evaluation criteria the greater is the tendency. A common example which arises in business is the evaluation of profit center managers on simple return on investment. The reluctance of an executive so evaluated to invest in new, more efficient but higher book value production equipment is understandable but is often detrimental to the long term profit performance of the firm.

Lorange discusses the problem this way [13]

> "There is a danger that the performance tracking process will lead to decision-making behavior which violates the overall organizational goal congruence requirement. This is partly due to the "technical" measurement problems .... These often stem from a desire to capture complex and multifaceted phenomena by means of a few variables..........."

The true function of a measurement system is to get an idea of the problems limiting achievement rather than to place blame. [14] No single measure or measurement system can totally assess the individuals contribution to intermediate and long term results or to the efforts of others. This is particularly true when the time horizon of long term goals

is extremely long as in the case of ship acquisitions. As an avowed purpose of the evaluation system is to increase the emphasis on long term goal achievement, any temptation to utilize the system for personnel appraisal should be resisted.

CHAPTER II CONCLUSIONS

Unless improvement in the ship acquisition process is to be left to chance, the degree of attainment of project goals must be observed and measured. Currently, by far the most emphasis is on attainment of short term goals e.g. minimizing acquisition cost. The most important goals in ship acquisition may be longer term in nature, e.g. minimization of total life cycle costs and performance adaptability.

A consistent and comprehensive evaluation system which assesses the degree of success of ship acquisitions should be developed. A key function of the system will be to collect and integrate the various data concerning life cycle costs and performance as the data becomes available for the different ship classes. The results contained in this information will be evaluated against the goals of the project, long and short term. The resulting assessments will be used for formulating improvements to the acquisition process. The historical data collected should also be

of use for budgeting, improving estimating relationships and providing "lessons learned" to new acquisitions.

The evaluation system should not be used for the appraisal of personnel performance nor is it intended for acquisition phase project control.

Chapter III will consider the development of a naval ship evaluation system, present individual sets of goals criteria for the three major goal areas, and discuss two approaches to the overall assessment of naval ship success.

CHAPTER II NOTES

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2. J. Ronald Fox, Arming America: How the U.S. Buys Weapons, (Boston, Division of Research, Harvard Business School, 1974).

3. Report of the Navy and Marine Corps Acquisition Review Committee, January, 1975.

4. Robert N. Anthony, Management Accounting: Text and Cases, (Homewood, Illinois, Richard D. Irwin, Inc., 1970, Fourth Edition).

5. Department of Defense Instruction 7000.3, "Selected Acquisition Report (SAR)", September 13, 1971.

6. Clark Graham, "The Operator and the Engineer - Partners in Naval Ship Design", Naval Engineers Journal, Vol. 85, No. 3, June, 1973.

7. Secretary of the Navy Instruction 7000.19B, "Department of the Navy Cost Analysis Program", March 12, 1975.

8. Department of the Navy Comptroller publication NAVSO P-3555, "Procurement Accounting and Reporting System (PARS)", January, 1975.

9. Chief of Naval Operations Instruction 3501.2C, "Naval combat readiness criteria", December 11, 1972.

10. See Department of Defense Instruction 7041.3, "Economic

Analysis and Program Evaluation for Resource Management",
October 18, 1972.

11. David J. Dunn, unpublished student paper, as quoted in C. Roland Christensen, Kenneth R. Andrews and Joseph L. Bower, Business Policy: Text and Cases, (Homewood, Illinois, Richard D. Irwin, Inc., 1973, Third Edition).

12. Ibid.

13. Peter Lorange and Michael S. Scott Morton, "A Framework for Management Control Systems", Sloan Management Review, Fall, 1974.

14. Christensen, et al, op cit.

CHAPTER III

A SHIP SUCCESS EVALUATION SYSTEM

INTRODUCTION

In this chapter a framework for a ship evaluation system is outlined. In the first part of the chapter, a discussion of the desirable traits of a ship evaluation system is presented. The prerequisites of the evaluation system include establishment of the need, a set of prioritized goals based on the need, and a definition of success in naval ship acquisition. A preferred definition of success is offered.

The second part of Chapter III includes development of sets of goal criteria for each of the three major goal areas. This is followed by outlines of a simple manual model and a more sophisticated, computerized simulation model for combining the sets of criteria and arriving at an overall evaluation of success. The latter model requires greater resources but may result in a more valid and objective evaluation scheme.

It is concluded that the proposed evaluation system is feasible, can be designed so that the criteria are relevant and the assessments arrived at, though not completely objective, will be more objective and meaningful than any currently available.

DESIRABLE SYSTEM TRAITS

The desirable traits of a ship acquisition evaluation system are much the same as those required of accounting principles - relevancy, objectivity and feasibility.[1] Relevant in that the measure used is meaningful and useful, objective to the extent that the assessment criteria is not influenced by personal biases or judgments and feasible meaning that the costs of implementation and the complexity of the system are within reason.

Total objectivity requires purely quantitative analyses. This ideal is unobtainable when evaluating a system as complex as a ship if relevancy and feasibility are to be maintained. The performance of a naval ship is particularly difficult to quantify completely. However, as the stated purpose of the evaluation system is to determine success as an aid in developing improvements in the acquisition process rather than to serve as a control system per se, the necessary sacrifice of objectivity is not so serious. The goal will be to utilize single and combinative quantitative criteria as long as it makes sense to do so; at the same time recognizing that employment of an "irrelevant criterion simply because it lends itself to quantification is a poor exchange for alleged objectivity."[2]

EVALUATION SYSTEM PREREQUISITES

It is assumed that a legitimate and well defined military need has been established and a ship has been selected as the

best alternative system to satisfy that need.[3] Although the proposed evaluation system has been specifically excluded from serving as a conventional control system, the basic steps required to formulate it are similar: goal specification, establishment of goal attainment criteria, results data collection, and evaluation of the degree of goal attainment.

GOAL SPECIFICATION

The first requirement is that a set of goals for the weapons system acquisition must be clearly specified. These goals are derived directly from the need and should reflect the planned resources allocation to meet the need.

Not only must the goals be clearly specified; they must be prioritized, or weighted. The reason for this requirement is that major project goals (cost, schedule and performance) are interdependent. A schedule change for example, will inevitably result in a cost change, particularly in an inflationary economy. The generally inverse relationship between acquisition cost and total life cycle costs was noted in Chapter II. Permanent performance deficiencies may result in a remaining gap in the need which must be filled ultimately.

It is impossible to optimize simultaneously interdependent goals. Some directives and project plans, however, seem to require this. For example, a recent Chief of Naval Operations directive notes that there had been little documentation

available "..... of the effort expended to maximize ships' mission effectiveness ..... while at the same time minimizing ship costs."[4] (emphasis added)

For the most part, however, current policy directives refer to a need to achieve a proper balance between major goals. For example, Secretary of the Navy Instruction 5000.1 "System Acquisition in the Department of the Navy", specifies

> "Continual tradeoffs shall be performed to optimize the balance between initial acquisition cost, estimated life cycle cost, schedule, and operational capability." (emphasis added)

The proper balance, i.e. the priority of goals, as well as actual selection of the goals, should be tailored to each project as the requirements of the needs and the priorities of the needs are different. Further, the relative importance of the goals should be specified preliminary to the search for the "best" system to fill the need. As noted in the 1972 "Report of the Commission on Government Procurement",[5]

> "The need should be separated from any particular system, and goals should be defined independently of the performance, cost and schedule characteristics of any particular system. .... the exploration of alternative solutions requires that these things be specified.
>
> * A statement of the problem to be

solved or the deficiency in mission capability, including those conditions that have created the problem or deficiency.

* The goals to be achieved by the acquisition program and their relative importance, including level of mission capability, program cost and when the capability should be available.

*The boundary conditions that must be met by any system, including constraints on physical size, operating conditions, tactics, and the talents of the users."

(emphasis added)

Once a specific ship acquisition project is formed in response to the need, the prioritized goal set should be formally specified in the project's charter. This will provide the acquisition group with the specific guidance needed to conduct consistent tradeoff analyses.

DEFINITION OF SUCCESS

Different ship acquisition participants and obervors view success differently. As previously noted, some emphasize achievement of one or more short term goals, others are interested in only the long term worth of the acquisition

Assuming that a prioritized goal set is established which accurately reflects the requirements of a legitimate need, the only definition of success in ship acquisition which makes sense is how well the actual results of the acquisition match the goals, including their relative importance.[6] The goal set must be flexible to the point that it continues to reflect the requirements of a changing need.

CRITERIA CONSIDERATIONS

The selection of appropriate standards by which to measure actual results against is not always clearcut. The choice is influenced by the goal in question, the phase of the acquisition, the observability and measurability of the data, and whether the assessment concerns actual versus planned results or one ship class against another.

Estimates for the major goal areas are required in the Operational Requirement Document which is prepared preliminary to Conceptual Design. These estimates are changed and refined as the design progresses. The estimates become thresholds when written into a Secretary of Defense approved Decision Coordinating Paper after the first Defense Systems Acquisition Review Council presentation (refer to Figure I-2 in Chapter I).

Most important to meaningful evaluation is that changes to estimates are fully substantiated as to cause and are completely documented. Traceability of estimates permit the evaluation results arrived at by using one standard to be adjusted for a prior or later standard as desired.

No one type of criteria is feasible for the evaluation of all the different aspects of a ship acquisition. The question of quantified versus qualitative criteria was addressed previously. Performance measures for complex systems are generally probabilistic at best, usually in the form of plots. The necessary combination of such criteria to arrive at higher level systems and functions evaluation results in an increasing need for judgment.

Measurement of results in the cost area can be mostly quantitative and in the form of variance analysis (meaning comparison of actual results to planned results rather than the statistical definition). The major questions to be answered are what are the appropriate costs to evaluate and what are the appropriate baselines to use. Still, judgment of the economic environment in which the acquisition took place is necessary in order to determine controllable and uncontrollable effects on costs.

The assessment of success in the schedule area deals primarily with how closely the ships are delivered to the schedule determined from the need. Quantitative variance

analysis is useful here also. The choice of what is the appropriate "required schedule" may not be clearcut.

After a short discussion of data requirements for the evaluation system, individual sets of criteria for each of the major goal areas will be developed in detail. Then, two different approaches to the combination of those criteria, so that an overall evaluation of success can be arrived at, will be developed.

DATA REQUIREMENTS

The evaluation system should have the data available that is needed to describe accurately the acquisition and permit in-depth assessment of what its results were and why. What must be avoided is the collection of data which is duplicative, irrelevant or more costly to collect than its value.

It is difficult to imagine that new data systems will be required to implement the evaluation system due to the numerous data sources discussed previously. The new function proposed is primarily that of collecting and assimilating data.

Close adherence to DOD Directive 5000.19, "Policies for the Management and Control of DOD Information Requirements", will help ensure data requirements are economical and concise. This directive directs that new information requirements be screened for suitability, and that they be designed to meet only essential needs.

SHIP PERFORMANCE EVALUATION

The performance of the ship system is key when considering the relative worth of ships.[7] An acquisition may be delivered on schedule and meet its cost target, but if it fails to perform the missions required of it, in no sense can it be considered successful. Conversely, in the opinion of at least one Ship Acquisition Project Manager interviewed by the author, costs and schedule overruns do not remain visible for long after delivery of the ships and thus the performance of the units is the only goal area which counts in the long run. The weakness of this viewpoint lies in the insidious effect acquisitions which are out of control can have on other acquisition projects, and thus on the overall defense posture. Neither short term nor long term goals can be ignored.

SHIP PERFORMANCE DEFINED

The definition of ship performance must include any feature that impacts directly or indirectly on the ability of a ship to carry out its assigned mission. This broad definition was earlier offered by Graham.[8] Graham includes combat ability (first and most important), mobility, survivability, habitability, maintainability, and future capability within the scope of the definition. Eckhart points out that

any measure of ship effectiveness must include availability - "ships at sea versus ships in being".[9] Sanders reiterated the point as follows[10]

> "Too many of our ships are only partially ready to carry out their missions on a continual basis. This places our Fleet and Force commanders, ..., into the position of assigning tasks on the basis of which ship is ready rather than which ship has the most built-in capability to do the job."

Depending on how the performance features are defined, others may be listed, such as the detectability of the ship. Since a change in capability in one feature area inevitably impacts on another, the evaluation of overall ship performance must consider many features, some of which are difficult to quantify.

For example, a new requirement to increase the size of the ship's crew will increase, unless compensated for by reductions in other performance features, the displacement and volume of the ship (possibly as much as 5 tons and 750 cubic feet per man). The increased displacement and size will slow the ship down and reduce its fuel endurance. To reclaim this loss in mobility performance will require increased horsepower in the propulsion plant. This in turn

will further decrease the endurance and additional fuel tankage will have to be added. The increased size and weight of the propulsion plant and fuel tankage increases the displacement and volume of the ship, etc. It goes without saying that each necessary increase in the ship will add to the acquisition and other life cycle costs.

Why it is necessary to include all performance features when considering ship performance is made clearer to the design layman when an analysis of their impact is made in terms of "pure" performance, such as the number of guns, as Graham demonstrated.[11] For example, it was found that the increased space built into our ship machinery spaces (increased maintainability) designed since World War II is equivalent in impact to two 5" light weight guns on a representative destroyer. Thus the question, simply put, is "Is the 'tradeoff' of larger specific machinery box with armament, ... representing a compromise of maintainability and habitability with combat ability, a good one?" The answer to this question rests in how well the overall results match the project goals set, i.e., the degree of success.

A FRAMEWORK FOR PERFORMANCE EVALUATION

Objective evaluation of complex system performance achievement has eluded systems analysts and controllers. As

Baumgartner observed in 1963,[12]

> "The main question to be resolved at this point in time is how to measure performance and how to plan performance. Effective answers will be developed just as surely as the final performance objectives of a project are achieved by effort and direction rather than by accident."

It appears that Baumgartner was overly optimistic as no completely objective and comprehensive measurement systems have been developed, to this writer's knowledge, that can account for different inputs, acquisition environments, and output form and purpose.

However, the development during the past three years of the Top Level Requirements (TLR) and Top Level Specifications (TLS) process provides the basic framework needed for a consistent and comprehensive (if not completely objective) ship performance evaluation system. The key, as will be discussed later, will be to extend this new requirements setting and performance measure specification process beyond the acquisition phase.

The following sections will discuss in detail the Top Level Requirements/Top Level Specifications process and the contents of the documents. A third key element of the performance evaluation system to be developed is a system of

consistent procedures for calculating the performance measures in the Top Level Specifications. An initial effort in this direction exists and will be discussed. The existing and planned standardized procedures (termed Performance Analysis Data Sheets) are presented, as are the Top Level Specifications performance measures, in a composite table of performance features (from the Top Level Requirements) and criteria.

The Top Level Requirements/Top Level Specifications Process

As noted in Chapter I, a draft Top Level Requirements, based on the results of Conceptual Design tradeoff studies and cost effectiveness analyses, is issued at the beginning of Preliminary Design.[13] The performance requirements in excess of minimum essential requirements are then traded off against cost and schedule requirements.

The Top Level Specifications breaks down the performance statements in the Top Level Requirements into basic functions.[14] An operational capability to "search, detect, classify and track air targets", for example, is divided into the four basic functions listed. A performance measure is used for each of the four. The function "search/detect" is logically measured by range. The Top Level Requirements may specify a minimum essential value or an acceptable range of range values. The Top Level Specification, however, will

state the predicted range performance.[15]

A further example is that the basic operational capabilities in mobility include "speed, endurance, seakeeping qualities, repair capabilities, etc." For an aircraft carrier escort, the Top Level Requirements may specify a minimum essential speed in a given sea condition but the Top Level Specifications will answer with predicted speed performance and speed degradation in given sea conditions.[16]

As the Top Level Specifications "presents the achievable ship within the cost constraint, it may well be that some performance measures in (the) Top Level Requirements cannot be met ..."[17] A Change in the cost constraint, required performance or design practices must then be negotiated and documented in the Top Level Requirements and Top Level Specifications.

At the end of Preliminary Design, "final" Top Level Requirements and Top Level Specifications (containing design specification and performance measures) are issued. Subsequently, all changes to either document are serialized and fully documented. (See Figure I-2)

Top Level Requirements Content[18]

The major sections of the Top Level Requirements include Operational Capabilities, Planned Use and Cost Constraints. The document is a translation of the military need into specific requirements. A brief description of it contents follows.

A. Operational Capabilities

1. Warfare Areas. This is a description of the

"combat tasks and functions the ship is intended to perform in appropriate mission areas". These mission areas, detailed in the Chief of Naval Operations Instruction 3501.2,"Naval Combat Readiness Criteria", include surface warfare, anti-air warfare, anti-submarine warfare, etc. The "warfare areas" correspond directly to Graham's "combat ability" performance feature. The section includes how the ship relies on and complements the capabilities of other types of units in the face of particular threats. Requirements related to the detection of the ship by different sensor types and requirements related to the survival of the ship, e.g. "hardness" to shock and air blast, are also described in this section.

2. Mobility Area. This includes the "operational capabilities required in the movement and transit of the ship". Listed in performance terms are speed, endurance, seakeeping, maneuvering,replenishment constraints and other operational constraints. Draft and beam restriction (to allow harbor and canal passage) as well as damage control and engineering casualty control requirements are described.

3. Command and Control Area. This area describes the provisions for planning and controlling operations of the ship and associated forces pursuant to the assigned missions. The extent of the operational capabilities and interfaces with other systems (by digital computer on large modern combatants) is detailed.

4. Fleet Support Operations Area. These are the "operational capabilities required of the ship to provide aid and

support to other units."

5. Non-Combat Operations Area. These are the operational capabilities expected which are not directly related to combat." Included are search and rescue, etc.

B. Planned Use

1. Environment. This area includes a description of the ship's expected operating environment as well as its allowable effect on the environment. The standard environmental conditions against which ship and subsystem performance are to be predicted as well as pollution related matters are detailed in this section.

2. Operational Availability and Ship Utilization. This section "describes the ship availability and readiness to get underway for specific ship readiness conditions in normal and altered conditions."

3. Maintenance, Overhaul, and Supply Support Concepts. This section is the intended maintenance and support philosophy for the ship. Minor and major repair frequency and duration and the level of on board maintenance capability and repair parts availability are specified.

4. Manning. The "manning philosophy, together with operational items which affect manning, such as degree of system automation, watch requirements, and experience levels and such other personnel related matters which constrain ship manning" are detailed here. Habitability and any special

safety requirements are included.

5. Wartime Use. This section "describes the anticipated operational profile and maintenance cycles during times of hostilities when the ship is subject to participation in combat". Subtopics include speed and time profile, maintenance and overhaul cycle, and operating and logistic support.

6. Peacetime Use. The same information as that specified in the above section is presented, but for during peacetime.

7. Other. In this area are planned use items which do not clearly fall under the previous six topics. Applicable exceptions to existing regulations and directives, as well as pertinent directives which are not normally invoked, are spelled out.

Top Level Specifications[19]

The Top Level Specifications, the design answer to the required operational capabilities and planned use assumptions of the Top Level Requirements, presents measures of ship performance and overall ship attributes utilizing three different classification systems. These systems are measures of overall ship attributes achieved, measures of ship system functional performance achieved (traces directly to the Top Level Requirements Operational Capabilities) and measures of

performance for ship subsystems.

The ship system functional performance measures included in the Top Level Specifications are generally the most meaningful ones to the ship operator. This serves the purpose of the evaluation system well as a primary interest is in the ship's functional capabilities at the mission performance level. The performance in any one mission area, e.g. anti-submarine warfare, may then be assessed by combining evaluations of the relevant functions, e.g. search, detect, classify, track and engage, of the anti-submarine warfare contributing systems.

In some cases, traceability exists between the Top Level Requirements and Top Level Specifications performance measures through common attribute names, e.g. speed, seakeeping, stability, vulnerability, availability and noise. There also exists direct traceability between the Top Level Requirements Habitability Standards and the Top Level Specifications Habitability Summary, the Top Level Requirements Supply Support Concepts and the Top Level Specifications Supportability, etc.

Performance Analysis Data Sheets

The Naval Ship Engineering Center, design arm of the Naval Sea Systems Command, is currently developing a system to provide "the analytical procedures required to calculate

the performance measures in the Top Level Specifications for a ship design.[20] The purpose of these "Performance Analysis Data Sheets" is to "set forth a single method for consistent application which will precisely define the Top Level Specifications performance measures and make visible all assumptions, margins, loss allowances, safety factors, etc., used in its calculation".[21] Performance Analysis Data Sheets standardized procedures and criteria are not being developed where it is considered that adequate standardized guidance already exists.

Performance Measures Set

By combining the performance requirements and constraints in the Top Level Requirements, the performance predictions and measures in the Top Level Specifications, and by utilizing the existing and planned standardized criteria calculations procedures specified in the Performance Analysis Data Sheets, a set of criteria for evaluating a ship's performance throughout its life cycle can be developed. Measurement of "success" in the attainment of performance goals can then be accomplished by utilizing primarily existing and planned systems. As noted previously, the major change required will be to collect actual results data and assess the performance against the requirements throughout the life cycle rather than just during the acquisition phase.

The table in Appendix A contains the proposed set of performance features evaluation criteria developed as discussed above. Included in the table are

a) the name and a description of the performance measures and ship attributes considered useful to the evaluation system, generally derived from the Top Level Specifications,

b) the Top Level Requirements performance objectives and planned use areas which are directly measured by the performance measure (indicated by a "T" for direct traceability) or are at least partially evaluated by the performance measure (indicated by an "I" for influence),

and,

c) the standardized procedures for calculating the performance measures which have been developed, or are planned for development. Note that only the title or a very brief description of the Performance Analysis Data Sheets or other standardized procedure is listed. Where a procedure is considered inadequate by the author for the purposes of the evaluation system, or is not known to be planned for development, a recommendation is included. Such recommendations are enclosed in parenthesis.

The next two sections will develop criteria of costs and schedule goals. Then the composite evaluation of success will be addressed.

COST EVALUATION

Acquisition cost is the most visible and controversial factor in naval ship acquisition. This situation results from the monumental cost overruns of the past two decades and the huge amounts required to purchase new major weapons systems. A single new nuclear powered aircraft carrier costs in excess of one billion dollars to acquire.

Never-the-less, a case was made in the previous chapter that the total life cycle cost is the more appropriate cost target to minimize. However, selection of the appropriate cost goals and their relative importance for each project is left to the goal setting process. The purpose of the evaluation system is to measure how closely the results match the original or current set of prioritized goals.

ACQUISITION PHASE COST CRITERIA

There is no scarcity of cost information during the acquisition phase. There is a problem, as previously noted, of obtaining contractor return costs. However, as the degree of engagement with the contractors increases and more of them meet the Cost and Schedule Control Systems Criteria (see Chapter I), useful return costs information should become more available and be of greater validity.

The Selected Acquisition Reports (SARS) required by

Congress[22] concentrate on acquisition costs and contain detailed acquisition cost variance analyses. Acquisition cost baselines for the evaluation system could be chosen from the cost estimates reported in the SARS, the Design-to-Cost constraints, or the estimates in the Decision Coordinating Papers. These estimates should all be in basic agreement.

The Naval Sea Systems Command's "Design-to-Cost Guide for new ships"[23] stipulates that major programs will use SAR specified guidelines (variance analyses) for explaining cost growth. The same directive requires that

> "A historical record of cost constraints, cost estimates, actual costs as they become available, and cost influencing factors will be maintained in order to provide the basis for explaining any cost increases."

The Design-to-Cost constraints are formulated in terms of "unit sail-away costs".[24] This is defined as

> "..... the estimated unit cost of construction of follow-on ships as delivered including government furnished equipment, and the installation and adaption of computer programs but excluding non-recurring costs and outfitting cost, in constant dollars of a given fiscal year, based on a given number of ships in the

series and a given delivery schedule."

Program acquisition cost variances, as reported in the quarterly SARS, are classified as resulting from[25]

a) quantity change

b) engineering change

c) support item change

d) schedule change

e) unpredictable change (strikes, acts of God)

f) economic change

g) estimating change (due to errors or revisions in estimating methodology and relationships)

h) contract performance incentives

i) contract cost overruns (underruns)

These reports therefore contain an adequate selection of acquisition cost criteria and analyses.

POST ACQUISITION PHASE COST CRITERIA

As previously noted, Department of Defense Directive 5000.1, "Acquisition of Major Defense Systems" requires that "cost parameters shall be established which consider the cost of acquisition <u>and ownership</u>" (emphasis added). The Office of the Secretary of Defense Cost Analysis Improvement Group charter[26] specifies that the group is responsible for providing a review and evaluation of independent and program cost estimates submitted at the Defense Systems

Acquisition Review Council presentations. The charter further stipulates that

> "These cost reviews shall consider all elements of system costs, including procurement, <u>operations and support</u> as appropriate." (emphasis added)

The "Department of the Navy Cost Analysis Program" was announced in March, 1975. The establishing directive[27] requires that costs be considered

> ".....for all phases of the weapon system, including the conceptual, definition, acquisition and operational."

The program requires the Chief of Naval Operations to

a) "Ensure that realistic cost estimates are provided for the planning, programming, and budgeting of systems and equipment acquisition.",

b) "Develop and maintain a cost data base for initial and follow on cost estimating, cost review and validation, and budgeting.",

c) "Provide guidance and develop costing methodology to ensure that the <u>total costs of acquisition and ownership</u> of weapon systems and force units are available to decision makers."

and,

d) "Maintain <u>force costing models</u> to facilitate consideration of alternative force structures and marginal

changes." (emphasis added)

Integration of the various sources and categories of life cycle costs is required for application of the evaluation system. The above plans and requirements, if carried through, should result in that integration.

Most of the data will be quantitative, and thus the criteria can be quantitative. However, some judgments must be interjected as to what indirect costs will be charged to a particular ship class. These overhead charges include the cost of maintaining and operating support facilities such as shipyards, repair ships, replenishment ships, supply depots, etc. Also, qualitative analysis of the effects of the resource constraints, and the political, economic and procurement environments is necessary, as previously noted.

Table III-1 provides a summary of the suggested baseline estimates for the principal life cycle costs categories. Actual costs incurred should be available initially from the Selected Acquisition Reports submitted quarterly by the projects, and later from the Chief of Naval Operations maintained force costing models and data bank. Schedule goal criteria will be addressed in the next section.

COST CRITERIA SUMMARY

COST CATEGORY	DEFINITION	BASELINE	REFERENCE/SOURCE
1. Program Acquisition Cost	Development, procurement and construction cost to acquire the ship, including outfitting and post - delivery costs.	Decision Coordinating Paper Estimate	a. Department of Defense Directive 7000.3, "Selected Acquisition Reports". (DODD 7000.3) b. Secretary of the Navy Instruction 7700.5, "Selected Acquisition Report", (enclosure 4, p. 2 to the instruction)
2. Logistic Support/Additional Procurement Costs	All remaining (after Program Acquisition Cost) procurement costs which require procurement appropriation. Examples		a. DODD 7000.3 b. Department of Defense Instruction 7045.10, "Five Year Defense Program Procurement Annex"

TABLE III-1

COST CATEGORY	DEFINITION	BASELINE	REFERENCE/SOURCE
	include replenishment spares, modifications, component improvement, common support equipment, production base support/facilities.		
3. Operating/ Support Costs	Maintenance, manpower and operational costs.	Decision Coordinating Paper Estimate	a. Department of Defense Directive 5000.1, "Acquisition of Major Defense Systems"
4. Conversion Costs	Major conversion costs incurred from modernizing the ship and/or enabling it to perform new mission requirements.	Chief of Naval Operations approved estimate	a. Chief of Naval Operations Instruction 7000.17, "Cost Analysis"

TABLE III-1

SCHEDULE EVALUATION

A major consideration, along with low unit acquisition cost for the Guided Missile Frigate program was to make contract award for production of the lead ship in less than two years after the requirement was levied in 1971.[28] Two and one half to three years is usually required for this process. The design management plan of having the Naval Ship Engineering Center immediately start Contract Design upon completion of Preliminary Design and soon afterwards bring in the lead ship and secondary contractors to aid in the design was developed primarily due to the schedule urgency.

The early ballistic missile programs were counted by most observors as successes rather than failures even though they incurred large cost overruns and there were deficiencies in their initial operational performance. They were "successful" because the goals during the "missile gap" era put primary emphasis on the early development of some sort of deterrent capability.[29] A RAND Corporation study of the ICBM programs characterized them as an example "where an immediate demonstration force is needed whether or not it works."[30]

Again, the point to be made is that success should be measured against the requirements of the need as expressed

in a prioritized goal set. It is entirely possible that, at least initially, rapid introduction of the system into the operating forces will be the dominant requirement.

As is the case for acquisition costs, the delivery schedule of a new ship class is monitored in the Decision Coordinating Paper/Defense Systems Acquisition Review Council and the Selected Acquisition Report processes. Delivery schedules are often unstable as a result of one or more of the below reasons,

a) overly optimistic estimates of development and construction time,

b) cost increases which force reductions and delays in awarding production contracts,

and,

c) yearly fluctuations in the number of ships authorized by Congress.

The actual delivery schedule is known well before actual life cycle costs and mission performance results. The recommended criteria is a simple variance analysis, as required by the Selected Acquisition Reports, using the baseline estimate as contained in the Decision Coordinating Paper. Schedule variances resulting from the causes cited above will require qualitative analyses of their effects.

In the remainder of this chapter, the combination of criteria into an overall success evaluation system is addressed

OVERALL EVALUATION

Having selected approptiate individual criteria for features of each of the three major goals, it remains to assess the combined results of the measure. One of the prerequisites specified was that clearly defined, prioritized goals would be stated for a project as derived from the established need. This can be done by simply ranking the goals in order of priority or by assigning weighting factors to the goals.

Such a specification of goal priorities can be viewed as the utility function, or criterion, to be optimized in the new ship class. As the goal weighting is determined from the requirements of the need, it may be necessary to change the respective weightings as the ship class progresses through its life cycle. A key element of success of a given project will be flexibility enough in the design to adapt to new mission requirements and resource constraints. Comprehensive documentation and tracking of the goal specifications will permit the evaluators to judge intellegently the degree of success relative to the current or past goal sets, or utility functions.

INDEPENDENT EVALUATION OF MAJOR GOALS

A strong case has repeatedly been made against evaluating one or the other major goals singally. No performance level is worth any cost, and likewise, inadequate performance to accomplish the mission requirements is no bargain. The requirements of the need and the relative priority of the need to other defense needs must be considered. Only by evaluating total results against the prioritized goal set can actual success be judged.

This is not to say, however, that the comprehensive data collected on ship acquisitions should not be utilized for comparing results in any particular area or for improving single design procedures and historically based estimating relationships. Such uses should be some of the major benefits of the evaluation system.

OVERALL EVALUATION MODELS

Two approaches to integrating the criteria into an overall evaluation model will now be discussed. The approaches are basically the same, but differ considerably in their sophistication and degree of automation.

A Manual Evaluation Model

Existing and already planned systems have been utilized to a great extent in formulating individual goal feature criteria and for data sources for the evaluation system. It is, in fact, the emergence of these new systems which have made comprehensive evaluation throughout a ship's life cycle possible.

In order to combine the interdependent criteria and goals, some sort of model must be utilized. The first approach to constructing and using an evaluation model continues the low additional resource requirement theme. In addition to low resource requirements, a simple approach which relies heavily on the judgment of the evaluators recognizes the following,

a) the extreme complexities of the system being evaluated,

b) the intricate interdependencies of cost, performance and schedule goals,

c) the difficulties of finding relevant quantified measures for every goal area,

d) the uniqueness of every project which will require a different evaluation model in each case,

and,

e) the problem of reducing every measure to a common dimension to permit straightforward combination.

These problems raise serious doubts about the validity and usefulness of a computerized model which would basically only require data input and then, with little evaluator manipulation, turn out an overall assessment of success.

A simpler, manual scheme will probably produce as good or better results at lower cost. The qualitative judgments necessary to make the results meaningful negate the value of a computer aid. Additionally, the assessments will be more acceptable to acquisition process participants, due to the relatively simpler approach used to arrive at them. So go the arguments.

The Basic Scheme

In each goal area, the myriad of data inputs would be collected and assessed using the individual criteria settled upon at the inception of the project. The evaluation criteria should have assigned to them distributed weights indicating the relative importance of each subsystem or subarea being measured. These criteria and the weighting of them should be developed by the acquisition project and approved through the Decision Coordinating Paper/Defense Systems Acquisition Review Council process. The criteria presented in the previous sections should be useful.

This is not a completely new requirement for the projects. Department of Defense Instruction 7041.3, "Economic Analysis and Program Evaluation for Resource Management",

requires that,

> "Criteria by which effectiveness can be evaluated are to be clearly specified at the inception of a program/project."

Development of the criteria set and assignment of relative importance weightings to the criteria by the project should promote acceptance of the evaluation results.

A number of schemes, including weighted point assignments, weighted variances or simply rankings, could then be devised which would serve to integrate the weighted criteria within each goal area. This is the same type process used by many projects to evaluate contractor proposals submitted in response to bid requests. Finally, by applying the weights contained in the utility function (prioritized goal set) to the results in each of the goal areas, an evaluation of the overall success of the project is possible.

A great deal of judgment will be required in assigning the weights and applying the criteria. The evaluation results will have to be qualified in detail. The subjective nature of the assessment, though a "number" is arrived at, should never be lost sight of. The final resulting evaluation, never-the-less, should be far superior to the fragmented, biased judgments emanating from various acquisition observors and participants.

A Brief Example

Table III-2 presents a sampling of example quantitative analyses for a fictitious ship class. The methods of calculating the goal features variances are arbitrary and other methods may be preferable.

After completion of the individual analyses, the next step is to assess the quantitative variances together with all relevant subjective information. The variances may be adjusted (reasoning should be carefully documented) or simply accompanied by modifying qualitative analyses.

The aggregation of variances to higher levels of goal features can then be accomplished by using pre-determined weightings. For example, consider the Costs goals. Table III-3 indicates how the evaluators might calculate weighted variances which indicate the degrees of attainment of the Costs goals. The sum of the weighted variances is then an indication of the degree of attainment of the prioritized Costs goals.

Table III-4 is an example of how a final figure which indicates the degree of success of the acquisition (i.e. how well the results match the prioritized goals set) can be arrived at. In the example, a negative (undesirable) overall variance of .02 from the prioritized goal set is calculated.

This example exercise is only an indication of the simple quantitative techniques which might be of use to the

SAMPLE MAJOR GOAL ATTAINMENT QUANTITATIVE ANALYSES FOR THE MANUAL MODEL

GOAL FEATURE	CALCULATION PROCEDURE	BASELINE	CURRENT	VARIANCE (parenthesis indicate undesirable)
A. PERFORMANCE				
1. Mission Support				
a. Anti-submarine warfare				
(1) Search/Detect	Mean value of probable ranges, averaged over three combat situations, averaged over three operating situations.	1800 yds	1900 yds	.06
(2) Engage	Ship and helicopter launched torpedos composite mean hit probability averaged over three operating situations, averaged over three combat situations.	.7	.6	(.14)
.				
.				

Table III-2

GOAL FEATURE	CALCULATION PROCEDURE	BASELINE	CURRENT		VARIANCE
.					
.					
.					
b. Surface warfare					
.					
.					
.					
.					
c............					
.					
.					
.					
2. Mobility Support					
a. Speed	Average of variance at several comparison points on speed vs power curves (current data curve vs baseline curve). Positive variance indicates overall greater speeds for given power levels. Variance composite would be penalized for failure to reach baseline maximum speed.	Baseline Speed	% Full Power	Actual Speed	Variances
		12 kts	10	11.6 kts	(.03)
		16 kts	22	16.1 kts	.01
		20 kts	30	21.0 kts	.05
		24 kts	50	25.0 kts	.04
		28 kts	100	29.2 kts	.04
				Mean variance	.02

Table III-2

GOAL FEATURE	CALCULATION PROCEDURE	BASELINE	CURRENT	VARIANCE
b. Range	....	...	....	....
c.				
3. Command and Control support				
4.				
B. COSTS				
1. Program Acquisition Cost	Variance between Decision Coordinating Paper estimate and latest estimate/actual cost. (Figures are in base-line year dollars.)	$1.2B	$1.4B	(.17)
2. Logistics Support/ Additional Procurement	....	.....	.....	.....

Table III-2

GOAL FEATURE	CALCULATION PROCEDURE	BASELINE			CURRENT	VARIANCE
3.						
4.						
C. SCHEDULE						
Delivery	Average variance between Decision Coordinating Paper schedule and current delivery schedule. Variance calculated by	Bslne Cons. Time (mon.)	Bslne Del.	Ship	Curr. Del.	Variance
		30	6/76	1	8/76	(.07)
		27	1/77	2	2/77	(.04)
		26	5/77	3	5/77	.00
		26	9/77	4	10/77	.00
	$\frac{\text{Baseline delivery - Actual delivery}}{\text{Baseline construction time}}$			Mean variance		(.03)

Table III-2

Table III-3

EXAMPLE COSTS GOAL ATTAINMENT CALCULATION

Cost Category	Weighting	Variance	Weighted Variance
1. Program Acquisition Cost	.3	(.17)	(.05)
2. Logistic Support/ Additional Procurement Costs	.1	.06	.01
3. Operating/Support Costs	.4	.02	.01
4. Conversion Costs	.2	(.07)	(.01)
		Overall Costs Weighted Variance	(.04)

Table III-4

EXAMPLE OVERALL GOAL ATTAINMENT CALCULATION

Goal	Weighting	Variance	Weighted Variance
Cost	.3	(.04)	(.01)
Performance	.5	.00	.00
Schedule	.2	(.03)	(.01)
		Overall Weighted Variance	(.02)

evaluators. The admonitions in the previous section against over-emphasizing or misusing the results of such an analysis merit constant awareness.

A Sophisticated Evaluation Model[31]

Advocacy of a more sophisticated evaluation model for ship acquisition success evaluation centers around the same observations of the complexities involved as made in support of the manual model. However, there is evidence that non-quantifiable goals and goal attainment criteria are often largely ignored when evaluation is done on a primarily intuitive basis. Goals criteria which can not be easily quantified should be evaluated by knowledgeable experts and assigned quantified, though subjective, ratings. Truly non-quantifiable goal criteria will serve little useful purpose as part of pertinent criteria used to determine the degree of success attained by a ship acquisition project.

Also, the limitation of human mentality severely limits the number of goal interdependencies that can be analysed under the previous model. The decreasing costs of time sharing and batch process computer systems, the steady advancement of new systems analysis techniques, and the previously noted continued expansion of defense acquisition information and control systems (creation, processing and preservation of large amounts of quantitative and qualitative

data), all suggest the feasibility of a sophisticated computerized simulation model.

Beginning in the early 1960's, the Department of Defense has made extensive use of systems analysis computer models to aid in appraising alternative weapon systems and to integrate long term planning with yearly budgeting. This proposal amounts to an extension of the usefulness of the long range planning models to include follow up evaluation of actual results fit to the requirements.

That the final assessment of success will be done by the model, independent of judgment, is not advocated. As Hitch stated in 1967,[32]

> "Systems analysis is simply a method to get before the decision maker the relevant data, organized in the way most useful to him. It is no substitute for sound and experienced military judgment, and it is but one of the many kinds of information needed by the decision maker."

Model Construction

The first step in building the model is the same as that for the simpler, manual model. The set of prioritized goals (the utility function) for the project is specified. This is the success reference against which the overall results will be assessed.

Early in the project life, management scientists will

conduct a series of interviews with key design, financial and management personnel associated with the project. The purpose of their interviews will be to discover the interdependencies of the project goals, subsystem and subgoal relationships, and the predicted range of effects on project outcome from externalities such as the funding schedule and amounts, the procurement and economic environments, etc.

The relationships will be designed into the simulation model. The selected criteria will be weighted and entered. Performance measures represented by probabilistic plots will be modeled by mathematical functions. Constraints which describe cost ceilings and minimum performance requirements will be used to flag "unacceptable" results.

The net contribution that subgoals attainment will make towards each of the multiple goals must be completely structured in the model. This can be accomplished by first specifying separate probability distributions for every underlying factor and then specifying factor interdependencies to form joint probability distributions.

The individual simulations of each of the major goal areas can then be jointly simulated by the same techniques as above. This approach is along the same lines as the prototype intertemporal goal programming model outlined by Ijiri.[33]

Model Usage

As data on actual results become available, they will be inputted to compare with the original estimated probability distributions and point estimates. The latter can be modified to reflect actual results and an increasingly accurate assessment of success obtained.

It is doubtful that any ships will ever encounter the exact operational and combat scenarios set up in the Top Level Specifications. However, the scenarios can be modeled in the war gaming activities of the Chief of Naval Operations organization. Actual ship performance results can be extrapolated into the war gaming data bank as they become available and actual scenario performance predicted with increasing accuracy. These war gaming results can then be compared to the baseline distributions in the evaluation model.

The computer model results in combination with qualitative information available to the evaluators should enable a relatively straightforward assessment of overall project success. By studying the varying degrees of success of different projects in conjunction with the projects' different imposed acquisition policies, acquisition environments and management and design techniques, intellegent formulation of high success potential improvements to the acquisition system process and structure should be enhanced.

The construction and implementation of the computer models should be done with as much involvement of project

personnel as possible. Obviously, special management science skills are needed. The operations research/systems analysis personnel utilized should have project experience where possible, and be primarily management oriented. A great deal of interaction between acquisition participants and the model builders is an absolute must if the model is to be valid and considered useful.

CHAPTER III CONCLUSIONS AND SUMMARY

A ship evaluation system should be objective, relevant and feasible. Total objectivity is prevented by the complex interdependencies and multi-variables involved which are often difficult to quantify independently, much less when in combination.

Prerequisites to ship success evaluation include a legitimate defense need which is best served by a naval ship, a prioritized set of cost, schedule and performance goals derived from the need requirements, and definition of what success is. Success is best determined by how well actual naval ship results, throughout the ship life cycle, fit the prioritized goal set.

The final steps in developing the evaluation system are criteria selection, evaluation model construction, and provisions for necessary data collection. Criteria and data requirements can, for the most part, be met by existing

and already planned systems.

Two approaches, differing in resource requirements, sophistication and degree of automation, have been presented for evaluating "overall success". The use of a "manual model" for overall evaluation, it is argued, is preferable because validity of the results requires a great deal of judgment be interjected into the system.

The computerized simulation program model, augmented by the evaluators' judgment, can account for more of the complex interdependencies involved in evaluating ship success. However, it requires greater resources to develop and use and its results may not be as acceptable to acquisition system participants and observors.

Neither of the models measure up to complete objectivity We never supposed they would. The manual model is certainly feasible and could probably be implemented in a short time. The greatest problem would probably be setting up the collection of the myriad of life-cycle data in a central location and processing it to usable form.

The computerized model is less feasible in that it would take a significantly greater amount of resources to implement and manage. It is definitely possible over a period of a few years, however. The relevancy of either model is dependent on the skill of those involved in the construction and implementation of the evaluation system.

Although the work required and its complexity may be apalling to some, the implementation of either of the two approaches could result in great payoffs for future acquisition efforts.

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RECOMMENDATIONS

It is recommended that a comprehensive ship life-cycle success evaluation system be developed and implemented. The framework provided in Chapter III for such a system should be roughly adhered to. Particularly important to follow are the concepts of utilizing existing systems outputs and insistence on clearly specified and prioritized goals at the inception of a project.

The standardized procedures for calculating the Top Level Specifications performance measures require further development and expansion to presently uncovered areas. The Performance Analysis Data Sheets provide a usable framework for this effort.

The decision on whether to take the "manual" model or computerized model approach for development of the overall success evaluation system should be carefully weighed. It would probably be prudent to start with the lower resource requirement system and then transition it towards the more sophisticated, computerized model. The analysis of this decision and a comprehensive trial implementation of a ship success evaluation system is recommended for a future thesis effort.

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SECNAV Secretary of the Navy — CNO Chief of Naval Operations

CHNAVMAT Chief of Naval Material

COMNAVSEA Commander, Naval Sea Systems Command

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APPENDIX A

TABLE OF PERFORMANCE MEASURES

KEY TO TABLE

"TLS"	Top Level Specifications
"TLR"	Top Level Requirements

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
Mission Support	General combat situations which are used in predicting functional performance are specifie for the below functions.	Warfare Areas (T) Environment (I) Manning (I)	
a. Search/Detect	The range predicted (at specified detection and false alarm probabilities) against a nominal target specified. Range performance in three operating situations (combinations of weather, sea state, target size/strength,etc.) are presented for each combat situation.		Range of detection of nominal anti-air warfare, anti-submarine warfare, and surface warfare targets under poor, typical,and good combat situations

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
b. Designate/ Acquire	Describes the probability of acquisition as a function of range against a nominal target on a continuous probability vs range curve, one for each operating situation. Separate plots for each combat situation.		Designate/acquire performance envelope - missile Designate/acquire performance envelope - gun (Designate/acquire performance envelope - torpedo)
c. Engage	Presents hit probability vs range for each type of ship's armament. Performance presented on continuous probability curves for three operating situations in term of cumulative, salvo, or single		Engage air target performance envelope - missile Engage air target performance envelope - gun Engage surface

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	shot probabilities, as appropriate, and including weapon reliability. One plot for each combat situation.		target performance envelope -missile Engage surface target performance envelope — gun (Engage sub-surface target performance envelope - torpedo)
d. Deceive/Deny	Presents the "cross-over" range (prescribed probability of detection where power of jamming/ deception signal equals own ship beam size/		Crossover range for deceive/deny function in anti-air warfare, surface, (and sub-surface) warfare

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	strength and radiated levels against nominal threats) in three operating situations. Range performance presented for each appropriate combat situation.		under poor, typical, and good environmental conditions.
e. Reaction Time	Describes the available reaction times against nominal threats in appropriate combat situations.		Ship system reaction times versus high level and low level threats.
Mobility Support		Mobility (T) Supportability (I) Manning (I)	
a. Speed	Ship speed versus power curve. Includes allowances for sea state,		Speed versus power curve for ship

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	wind, hull fouling, etc.		
b. Endurance (Range)	Ship endurance (range) capability as a function of ship's speed.		Ship endurance (range) versus ship speed (for various sea states)
c. Mobility Control (Maneuverability)	Appropriate performance parameters describing the ability of the ship to achieve speed and directional control.		Maneuverability performance tolerance. Turning radius (and rate) vs speed. Ahead acceleration, astern acceleration.
d. Navigation	Predicted capabilities of the navigation system to		Navigational accuracy -

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	fix accurately the geographical position of the ship.		navigational systems
e. Anchoring/Mooring/ Towing	Anchoring capabilities in terms of depth of water and sea/wind. Mooring capabilities. Towing capabilities as a function of sea state and speed.		Mooring system - maximum capability. Anchoring system - maximum capability. Towing capabilities-sea state versus speed.
Command and Control Support		Warfare Areas (I)	
a. Process Time	Mean elapsed time (at prescribed success level) to complete stipulated sequences - operating situations		Elapsed time to complete command and control time critical processes.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
b. Process Accuracy	Command and control capacity as a function of tracking load and system conditions. Continuous plot of track capacity versus percent of processor time for stipulated mixtures of local and system tracks.		Command and control data accuracy.
Ship Support	Plausible range of operational situations which might be encountered are specified.	Mobility (T)	
a. Auxiliary Power	Capabilities of the electrical, hydraulics and compressed air subsystems. Capabilities expressed in terms of capacity		60 hertz electric power margins, 60 hertz electric power casualty

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	in kilowatts, horsepower, British thermal units per hour, etc., that can be provided by the proposed subsystems configurations plus the required loads over the range of operating conditions. (Frequency and voltage regulation of electrical systems. Quality of dry air.)		recovery, 400 hertz electric power margins, (400 hertz electric casualty power recovery), 26 volts DC power margins, (Frequency and voltage regulation vs load), (Quality of dry air vs requirements).

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
b. Environmental Control	Comparison of general ship cooling and heating capacities with heating and air conditioning loads for cold and hot day conditions respectively.		Environmental control performance capacity vs demand.
c. Pollution Control	Legal requirements for effluent quality met.		Capabilities to control quality of effluents vs requirements.
d. Replenishment	Underway replenishment capabilities - performance in terms of rates of transfer for fuel, cargo, etc., for various sea states and ship separation distances.		Refueling rate, volume vs time, Refueling rate, volume vs temperature, Fuel receiving

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
			rate, volume vs temperature, Total time for refueling (receiving) Solids transfer, volume vs time.
e. Damage Control	Performance capabilities to fight fire and flooding		Numbers and capacities of damage control equipment, repair stations and Damage Control Central (For each fire class, probability of extingui-

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
Platform Feasibility (Sea Environment Survivability)		Environment (T)	
a. Structural Strength	Applicable design criteria for the ship's structure.		Structural strength - per Naval Sea Systems Command publication 0900-006-5600.
b. Stability and Buoyancy	Applicable stability and buoyany criteria - performance predictions expressed as height of center of gravity (KG) margins.		KG margin (intact stability) (per Naval Sea Systems Command publication 0900-006-5600 or Society of Naval Architects and Marine

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
			Engineers Sarchin & Goldberg criteria
Survivability (Combat Environment)		Environment (T)	
a. Protective Features vs Design Threats	Design weapon threats and the corresponding features to be incorporated to improve survivability against them.		Probability of 50% degradation vs damage radius.
b. Damaged Stability, Reserve Buoyancy, and Hull Strength	Predicted stability, reserve buoyancy and hull strength after flooding damage of varying severity - performance predicition include center of gravity margins and the sea state which hull is expected		KG margin (damaged stability) (per Society of of Naval Architects and Marine Engineers Sarchin & Goldberg criteria.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
			shing vs size and location of fire) (Pumping capacities vs location flooding).
Human Support		Wartime Use (T) Peacetime Use (T) Manning (I) Mobility (I) Warfare Areas (I)	
a. Habitability	Significant habitability requirements and constraints.		Space allocation vs Chief of Naval Operations Instruction 9330.5 series requirements.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
b. Environmental Requirements	Standards and limits followed for certain environmental conditions, e.g. noise and vibration limits for space categories for reasons of crew comfort. Color, lighting, ventilation, and work environment described.		Environmental provisions vs Chief of Naval Operations Instruction 9330.5 requirements.
<u>Deployable Systems Support</u>		Warfare Areas (T) Environment (I)	
a. Deployable Systems Handling	Deployable systems requirements and performance measures.		Limiting roll angles for helicopter handling.
<u>Margins and Growth Provisions</u>	Principal margins to be provided.	(Influences all future capabilities.)	Margins and growth provisions.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
c. Structural Protection Against High Explosive Weapons	Describe armor and structural protection to be provided - predicted capability of the protection provided.		Degradation vs keel shock factor.
d. Shock Resistance of Equipment	Shock hardening and/or shock isolation provided against underwater explosions for various classes of equipment - predicted attack level in terms of the shock factor and overall body velocity (for nuclear underwater explosions) which the equipment is expected to survive.		Degradation vs overpressure.
e. Protection Against Nuclear,	Protective features to be provided against nuclear air blast,		Contamination density levels

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
Biological and Chemical Weapon Effects	electromagnetic pulse, transient radiation effects, nuclear radioactive fallout and biological and chemical warfare agents.		Contamination density levels and radiation levels in manned spaces.
f. Damage Control Systems After Damage	Predicted performance of the damage control equipment and systems after specified amounts and types of weapon inflicted damage.		(Same as for Damage Control capabilities before damage, except for specified loss of capabilities.)
g. Capability Survival Probability After Damage	Predicted survival capability of the ship after physical damage by weapon effects - probabilities of retaining		(Ship and functional capability survival probability after

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	critical ship functions after specified numbers of hits.		damage vs damage radius and location.)
Availability	Ship, subsystems, and functional performances in terms of their respective probabilities of successful operation over intervals of time on prescribed time lines.	Availability (T) Supportability (I) Manning (I) Wartime Use (I) Peacetime Use (I)	
a. Ship System	Ship probability of being ready and reliable (PRR) through the time line period. PRR is the product of ship readiness at that time and ship reliability for the duration of a combat mission phase. Ship readiness		Curves of subsystem reliability vs mission time (curves of subsystem availability vs mission time)

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	is the probability the ship is operating as required during the mission. Ship reliability is the probability the ship will continuously perform over the time line period when operated under stated conditions.		
b. Functions	Functional reliability, i.e., the probability that mission essential ship functions, when required during the time lines, will provide a continuous capability over the time line period.		(Curves of functional reliability vs mission time.) Curves of subsystem availability vs mission time.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
Environmental Degradation	Predicted degradation in performance of particular ship subsystems caused by actual operating conditions compared to ideal performance.	Ship Attributes (T)	
a. Seakeeping	Predicted degradation and/or minimum performance capability of the ship in the motion environment generated by the ship's being in a seaway.		Curves of motion and power limitation on ship's speed vs sea state for head seas, Curve of helicopter operations degradation vs significant roll angle.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
b. Compatibility	Electromagnetic and acoustic compatibility measures - predicted levels of ship generated interfering signals at radar and communications antennas - radiation hazard level predictions - self noise levels at ship sonars as a function of ship speed and caused by transmission of machinery noise/vibration, flow noise, and cavitation.		Interference to noise ratio (decibels) vs frequency for electromagnetic interfernce and electromagnetic compatibility. Curves of sonar self noise vs ship's speed, (Curves of sonar noise vs operating machinery speeds and combinations.)

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
Detectability	Signatures of the ship system which can potentially be exploited by an enemy using appropriate sensors.	Ship Attributes (T)	
a. Radiated Noise (Underwate/Airborne)	Underwater acoustic sound pressure levels radiated by the ship as a function of ship speed - airborne noise sound pressure levels, if appropriate - radiation patterns centered on the ship, if appropriate.		Underwater radiated noise level envelope, (Airborne radiated noise level envelope).
b. Electromagnetic Radiation	Average signal strengths radiated beyond the ship envelope as a function of ship readiness conditions across frequency bands of interest. Does not include intentional		Unintentional electromagnetic radiation signal level envelope.

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	radiation , e.g. by a search radar or radio transmitter, but does include such equipment leakages in standby status or while radiating into a dummy load.		
c. Infrared Radiation	Ship's average infrared intensity level differential with the background and for the principal "hot spot", its relative location and intensity level differential with the sea background.		(Infrared intensity level envelope in sea environment.)
d. Optical Detection	Ship's probable range of being detected as a function of operational limitations (light or darken ship, speed, etc.).		(Optical detection range vs speed for given combinations of background light

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLR OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
			intensity, light or darken ship conditions, aspect, etc.)
e. Magnetic Signature	Ship's probable range of being detected as a function of target angle and magnetic treatment as sensed by a detector of nominal sensitivity in a typical situation (latitude and geological background noise level).		(Probable detection range vs magnetic intensity for given target angles, degaussing, and geographical locations.)
Supportability	Philosophy of Integrated Logistics Support - level of support to be rendered by ship's force (Organizational level maintenance),	Supportability (T) Environment (I) Availability (I) Wartime Use (I)	

TLS PERFORMANCE FEATURE CATEGORY	TLS PERFORMANCE MEASURE DESCRIPTION	TLS OPERATIONAL CAPABILITIES/ PLANNED USE AREAS	STANDARDIZED CALCULATION PROCEDURE
	tender repair (intermediate level maintenance) and shipyard (depot level maintenance)	Peacetime Use (I)	
a. Operating Logistics	Operating cycle and the general ship requirements for consumables.		Operating logistics - Naval Sea System Command Operating Logistics Support Criteria (draft) document.
b. Maintenance	Maintenance philosophy - which type of maintenance is to be done at which level for major critical pieces of equipment and subsystems (i.e., rotatable pool concept for gas turbine power modules, etc.)		Maintenance - Naval Ship's Engineering Center "TIGER" computer program.